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# QRP

## the challenging world of low power transmission

another Practical Wireless publication

THE RADIO MAGAZINE

# C. M. HOWES
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**ST2 Kit £7.30 Assembled PCB module £10.80.**

| | | |
|---|---|---|
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| **PA2/15** 15W 2M Linear. | **Kit £18.90.** | **Assembled £23.90.** |
| **PA2/30** 30W 2M Linear. | **Kit £22.90.** | **Assembled £27.90.** |
| **CO1** Change-over unit. | **Kit £9.80.** | **Assembled £13.80.** |

We have not got enough space in a single page to tell you all about each product, or in fact anything at all about some of our kits. So if you would like further information, simply drop us a line enclosing an SAE, we have an information sheet on each product as well as a general listing of all our goodies. The prices in this ad. should hold until the end of August 85, but we do have to reserve the right to alter them or our products if the need arises. We aim to keep delivery within 7 days.

**PLEASE ADD 60p P&P** to your total order value.

**73 from Dave, G4KQH Technical Manager**

INTRODUCING

# QRP

**the challenging world of low power transmission**

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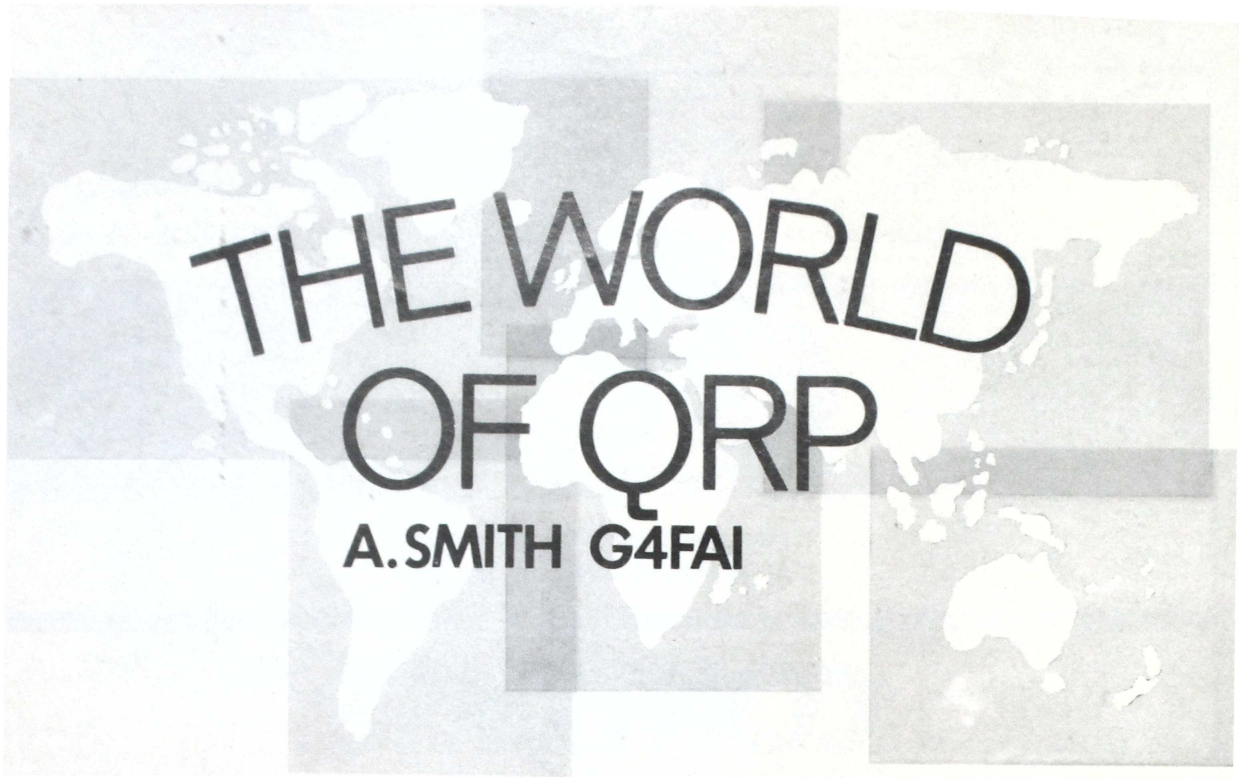


# THE WORLD OF QRP

A. SMITH G4FAI

A newcomer to amateur radio glancing through most magazines concerned with the hobby could be excused for thinking that to get on the air it was necessary to have very sophisticated, high-powered and expensive equipment.

This is not the case and there is a world-wide movement within amateur radio dedicated to using inexpensive, sometimes very simple and often home-built, low-powered equipment. This is the world of QRP—a world of challenge, where patience is a necessity rather than a virtue!

## What is QRP?

The code QRP is used by radio amateurs to refer to low power operation. This has been adapted from the International Q code, where QRP? means "Shall I reduce power?" and QRP means "Reduce power".

The G-QRP Club in this country defines QRP as low power radio communication using five watts input or less. The QRP Amateur Radio Club International, in the USA, defines it as five watts output although for many years they called 100 watts QRP and 5 watts was QRPp, extra low power! The important thing is that the power levels are lower than those normally used, thus providing a challenge to try harder, and to use your equipment more skilfully, than other operators.

Many QRP stations operate with c.w. (Morse code) because, in a situation where every aspect has to be optimised to be successful, c.w. is the most effective mode of communication in the crowded h.f. bands. Telephony has its place however and there are QRP stations who operate almost exclusively on the microphone.

## Construction

The sophistication of modern amateur radio tends to give the impression that home construction must be a thing of the past for all but the most talented, and much of what is made today is usually ancillary equipment rather than the actual transmitters or receivers.

This is where the keen QRPer scores. There are many circuits and designs available for rigs capable of putting out a few watts of c.w. These circuits are not too difficult to make, don't make too much of a hole in the pocket, and give enormous satisfaction when they result in amateur contacts tens, hundreds or thousands of miles away. Of course all the ancillary equipment can be home-made as well. It is not necessary to use the heavy duty components specified for use with higher powers. There is plenty of scope for experiment, and circuitry can often be simplified.

## G-QRP Club

The G-QRP Club is the largest QRP club in the world, although it was started in 1973 almost by accident. The Rev. George Dobbs G3RJV found he was working a number of other QRPers on 7MHz (40m). Whilst in contact with G2NJ he hit on the idea of bringing together the QRPers in the UK to exchange circuit ideas etc. He publicised the idea, about 30 people replied, and the club just grew from there. Membership is now world-wide and, at the time of writing, stands at over 1300.

The title for the club's journal—*SPRAT* (Small Powered Radio Amateur Transmission) was suggested as a joke but the name stuck. It is now a quarterly publication containing many circuits, technical hints and ideas for QRP projects, together with club news, award and contest information and other items of interest to QRP operators.

The club has a data sheet service, Morse training tapes, an awards scheme which culminates in a QRP Master's award, and a QSL bureau. A new venture, published in 1982, was a Circuit Handbook, which is literally "the best of *SPRAT*" and which is essential reading for all QRP enthusiasts.

On all amateur bands there are internationally known QRP frequencies and the club has regular activity periods each week, together with special activity weekends several

times a year, centred round these frequencies. A particularly successful event is the QRP Winter Sports which is held in the week after Christmas and which results in some fine contacts over quite remarkable distances. The high spot of the 1981 event was the performance of the Japanese station JA6VZB using five watts, who worked six European QRP stations in England, Scotland, Italy, Czechoslovakia, Sweden and Holland.

There were plenty of transatlantic contacts with both Canada and the USA. One station, member WB2RZU, in Long Island, worked GM3OXX in Edinburgh using only 500 milliwatts.

The club was particularly honoured to be asked by the Radio Society of Great Britain to provide the transmitting station for the RSGB h.f. Convention held near Oxford in June 1982. The main station was a Ten-Tec Argonaut 515, with five watts input, but home-constructed equipment was also used. The club mounted an exhibition of equipment made by members and there was considerable interest in the station and the exhibition throughout the convention.

## World QRP Federation

A fairly recent development in QRP affairs has been the formation of the World QRP Federation, which was formed on the initiative of the G-QRP Club in September 1980 on the suggestion of Gus Taylor G8PG, Communications Manager of the club.

WQF has member organisations in all continents and in the short period it has been in existence it has revolutionised the world QRP scene. Regular contact has been maintained between all members so that major activities are publicised on a world-wide basis. Intercontinental two-way QRP communication is becoming more and more commonplace. Smaller and newer organisations are able to draw on the support and experience of the larger groups during their formative period and it is possible to get world agreement on matters of common interest, including the definition of QRP power levels, QRP frequencies for international working, and so on.

There is a considerable exchange of technical information and now there are international project years in the QRP field. The project for 1982 was for all member organisations to increase membership by at least 10 per cent and it looks as if that was more than achieved. This year's project will probably be a drive to increase the amount of home-construction and experimentation amongst QRP operators.

WQF is a remarkable achievement, demonstrating how groups of radio amateurs world-wide can work together in a common interest. In the process they are breaking down barriers and fostering international understanding and friendship. As Gus Taylor, now WQF Secretary, says, "this alone would be enough to justify the existence of WQF".

**Table 1**

**World QRP Federation Members**

| Club Name | Country |
|---|---|
| ARI QRP Club | Italy |
| DL AGCW | West Germany |
| EA8 QRP DX Club | Canary Islands |
| G-QRP Club | United Kingdom |
| Grupo QRP Do Brasil | South America |
| Michigan QRP Club | USA |
| JARL QRP Club | Japan |
| QRP ARCI | USA |
| VK QRPp CW Club | Australia |
| Benelux QRP Club | Netherlands & Belgium |
| QRP Klub YU3EOP | Yugoslavia |

## Operating Pleasure

It would be misleading to suggest that QRP operating consistently results in long distance contacts. That is not its objective. QRP is always a challenge, whether the other station is near or far. Conditions are rarely ideal, although sometimes the signal report received from the other station is quite surprising, and the satisfactory completion of a contact is always a pleasure. There is usually something interesting about a QRP transmission to a higher-powered station, that adds to the QSO, but the best of all is when the other station is also QRP. There is an immediate common bond, and a willingness to be patient and to persevere when other stations would give up in difficult conditions. This leads to a need to develop good operating skills and the ability to get the best from the transmitter, receiver and antenna system. The friendliness, courtesy, high operating standards, the difficulties to be overcome, the triumphs and the disappointments all bring back something from the earlier days of amateur radio, and for many this is the attraction of QRP.

Although many QRP contacts are made through c.w. there are stations who use telephony as well. There are, perhaps, not so many home constructed transmitters for this mode, but there are available commercially several transceivers designed specifically for low-power working, or having the facility to reduce power to QRP levels. Eminent amongst the former is the Ten-Tec Argonaut, much beloved by its owners, and giving five watts input on both c.w. and s.s.b. from 3·5–30MHz.

The G-QRP Club has a s.s.b. net but probably the best example of what can be done here is to be found in the QRP sections of the various international contests each year, when some quite staggering scores are built up from contacts around the world.

## Antennas

QRPers go to a lot of trouble to get an efficient transfer of power from the transmitter to the antenna. A beam would seem to be the obvious choice to ensure that all the transferred power went in the same direction. Yet, surprisingly, many QRP operators do not use beams at all, and the most popular antennas seem to be various arrangements of dipoles, ground-planes or long wires.

One operator who does use a beam, however, is Chris Page G4BUE, who spent many hours adjusting his four-element trap beam to get the best possible match on his favourite frequencies without the need for an s.w.r. bridge or a.t.u. in the feed line. He then dropped the input power of his Argonaut progressively from five watts to five milliwatts. At one watt he worked 51 countries, 500mW gave him 17, 150mW produced 7 and with 5mW he crossed the Atlantic on two occasions. Amongst all these were countries like Haiti, Iceland, Mauritania, Iran and Zimbabwe, which many operators rarely work with higher power!

**The Argonaut 515 QRP transceiver**

During a contest in May 1981 Chris lowered the power of his rig even further. He obtained four transatlantic reports on 21MHz with an output power of less than 1mW, and two of these were at 200 microwatts!

He obviously spent a great deal of time and trouble on these experiments but it is a remarkable demonstration of what can be done with extremely low power.

## Looking Back

There is nothing new about QRP. The RSGB's *T and R Bulletin* reported on a "One Watt" competition in 1931 which showed that communication could be maintained over 800–1000 kilometres on the 7MHz (40m) band with reasonable consistency. The winner of the contest, incidentally, was G2OL of Ealing with a score of 165 points.

In June 1925 *QST*, journal of the American Radio Relay League, reported a number of low power contacts using powers ranging from 1·95W to 3mW. The star of the report was Edwin Miller 8KW, who, in 14 days worked 29 stations at distances between 483 and 1770km using an input of between 1·7W and 200mW with a one-valve transmitter. A particularly interesting transmission was that between G5SI in Shrewsbury and 1PL in the USA, a distance of 5311km using 1·95 watts input. The report commented, "the beauty of this work is not only the results, if any, are spectacular, but that the apparatus required is inexpensive, easy to assemble and adjust". The message is exactly the same today!

**Table 2**
**G-QRP Weekly Activity Periods**

| | | |
|---|---|---|
| Sunday | 1100–1230GMT<br>1400–1530GMT | on all c.w. calling frequencies |
| Wednesday | 2000 local time | 3·560MHz |

**Table 3**
**International QRP Calling Frequencies**

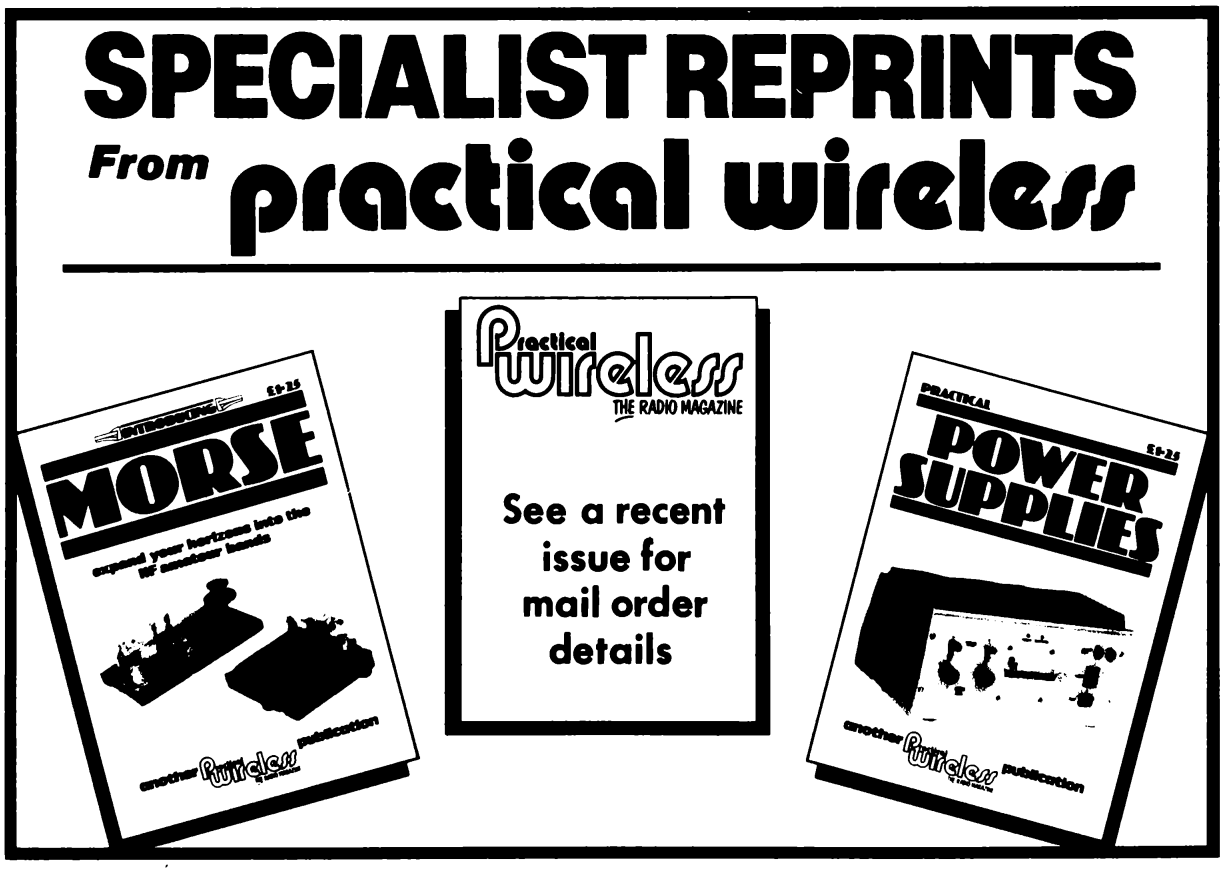
| Band | c.w. MHz | s.s.b. MHz |
|---|---|---|
| 3·5MHz (80m) | 3·560 | 3·690 |
| 7MHz (40m) | 7·030 | 7·090 |
| 14MHz (20m) | 14·060 | 14·285 |
| 21MHz (15m) | 21·060 | 21·285 |
| 28MHz (10m) | 28·060 | 28·885 |

## Reduce Your Power

QRP is worth a try, and there's no need to go for five watts straightaway. If you can reduce the power of your rig to, say, 20 watts, you will be quite surprised at what you can do. After that, keep reducing the power until you become a true QRPer! No more TVI, and, if a lot of other stations did the same, think how much quieter the bands would be!

The challenge is there. The sense of achievement has to be experienced to be believed. It need not be so demanding technically as some other aspects of amateur radio but it is just as satisfying, challenging and absorbing as any of them. Above all, it's fun!

Whether you are an experienced operator or a newcomer to the hobby, why not give it a try? ●

# PW DART QRP TOP BAND TRANSMITTER

## by Rev G.C. Dobbs G3RJV & Colin Turner G3VTT PART 1

I remember well my first venture into phone on Top Band. It was in the days that a.m. ruled. I had built the obligatory valve transmitter for Top Band: EF50 v.f.o., EF50 buffer and 807 p.a. with cathode of the 807 keyed for c.w. operation. Then following the advice of an old timer I put a carbon microphone in the key socket and shouted into it. Lo and behold—amplitude modulation . . . and a sore throat. It all seems so complex in these days when single side band holds sway. What we offer here is a simple means of being able to put a voice transmission onto an amateur band.

Each year my family and I leave the safety of Birmingham and make a sojourn in Kent to the G3VTT household. During these visits we usually make time from wife pacifying and child amusing to work on some project in the shack. On one such visit I found Colin towards the end of making a little double sideband suppressed carrier (d.s.b.s.c.) transmitter for Top Band and we completed the project together. I liked it. Practically nothing in the box and it put a useful signal onto the 1·8MHz (160m) band. The circuit appeared shortly afterwards in *SPRAT*, the journal of the G-QRP Club[1] and was named BREN after Colin's long suffering wife. Several G-QRP Club members built the transmitter with success. Bristol even produced a small 1·8MHz band net of people using the design. I have added a little to the circuit, standardised the components for ease of purchase, presented a p.c.b. layout and we now offer it to wider audience as the *PW* Dart.

The circuit offered has several advantages. It uses cheap bipolar devices plus a couple of common f.e.t.s. together with standard inexpensive components. The circuitry is simple enough for most amateurs to tackle. It has been built without problems by a number of people. But best of all, it puts a useful couple of watts onto the 1·8MHz band on c.w. and the d.s.b.s.c. signal is of good quality and taken by most people for an s.s.b. transmitter. Many modern multiband transceivers do not offer a 1·8MHz band option and this is a simple way to get on that band.

What are we talking about when referring to d.s.b.s.c.? Well, it is an amplitude modulated signal in which the two sidebands are transmitted but the carrier is removed.

## BUYING GUIDE

The Jackson air-spaced capacitors used in this unit are available from Bi-Pak Semiconductors. The SBL-1 double balanced mixer is obtainable from Cirkit. The author's prototype was housed in a box obtainable from Minffordds of Sun Street, Ffestiniog, Gwynedd LL41 4NE. All other components are readily available from advertisers in PW.

**Approximate Cost** £55

**Construction Rating** INTERMEDIATE

## The Circuit

The complete circuit of the transmitter is shown in Fig. 1. The key item in the circuit is the mixer, it is the splendid SBL-1 Double Balanced Mixer module. The v.f.o. signal on 1·8 to 2MHz is fed into one port and, in theory, no signal will emerge at the output port (pin 1) unless the mixer is unbalanced with a signal on the third port. If this port is supplied with an audio signal, a double sideband r.f. signal will emerge—suppressed carrier because it only appears in response to the audio input. If a d.c. voltage is keyed onto the third port a keyed c.w. signal will emerge. In practice a little of the v.f.o. signal will leak through the double balanced mixer (d.b.m.) but with careful construction and layout this leakage is minimal.

The v.f.o. is a simple common drain Colpitts Oscillator, Tr1, with a single buffer stage, Tr2. The output from the source of Tr2 gives a reasonable match into the d.b.m. The Power Amplifier Board may lack sophistication but uses inexpensive devices in a linear arrangement to produce some 2 watts of output. It consists of a pre-driver BC108, a driver 2N3053 and a pair of 2N3053 transistors

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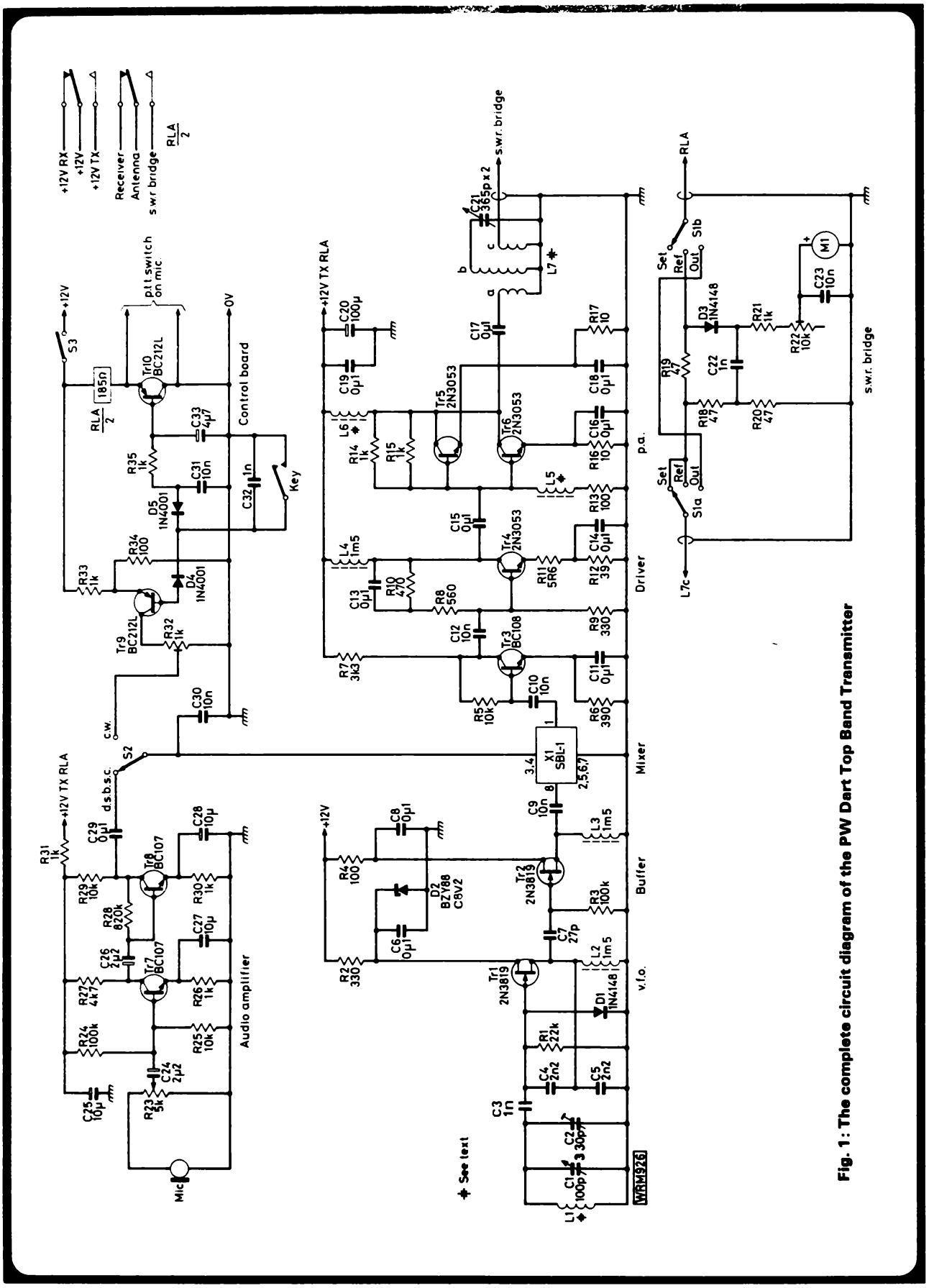
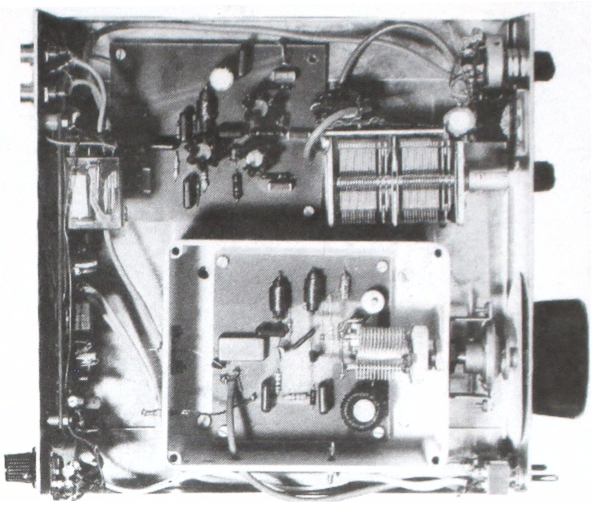



**Fig. 1: The complete circuit diagram of the PW Dart Top Band Transmitter**

in the final. Other similar bipolars will probably give much the same results. The audio signal comes via a very scant two-stage amplifier, Tr7 and Tr8, which has more than adequate gain for full output from a cheap medium impedance CB type microphone. I hate microphone hugging and found even without full gain I could hold the microphone almost a metre from the mouth. The transmitter may even be capable of the "marble hall" effect that Italian s.s.b. operators seem to love.The key operates two d.c. switches Tr9 and Tr10. Keying produces a voltage through Tr9 onto a preset R32 which provides the d.c. voltage for the c.w. signal. Keying Tr10 operates a relay, RLA, with a degree of hold on provided by C33 to give a semi-break in effect. On d.s.b.s.c. operation the "press-to-talk" switch shorts out Tr10 to put the circuits onto transmit. The two-pole changeover relay contacts switches the antenna between the transmitter and receiver and also provides 12VTX on transmit and 12VRX on receive from the 12 volt power line.

The output from the transmitter is tuned by a single tuned circuit, L7/C21, which has two small input and output link windings. This gives a low impedance output but most operators on Top Band cannot provide a 50Ω antenna . . . oh for the space of the dipole! So an integral s.w.r. bridge circuit is provided on the output. The circuit chosen has several advantages in that not only is it simple but also it offers impedance protection to the p.a. transistors and allows tuning-up to be a simple three switch action. The bridge is a resistive s.w.r. bridge based upon the Wheatstone Bridge beloved of physics masters. Resistors R18-20 provide three arms of the bridge, the fourth being the impedance of the antenna. When the output "sees" 50Ω the sensing circuitry, D3/C22, are at a null and the



## ★ components

**Resistors**

*Carbon Film ¼W 5%*

| | | |
|---|---|---|
| 5·6Ω | 1 | R11 |
| 10Ω | 2 | R16, 17 |
| 39Ω | 1 | R12 |
| 47Ω | 3 | R18-20 |
| 100Ω | 3 | R4, 13, 34 |
| 330Ω | 2 | R2, 9 |
| 390Ω | 1 | R6 |
| 470Ω | 1 | R10 |
| 560Ω | 1 | R8 |
| 1kΩ | 8 | R14, 15, 21, 26, 30, 31, 33, 35 |
| 3·3kΩ | 1 | R7 |
| 4·7kΩ | 1 | R27 |
| 10kΩ | 3 | R5, 25, 29 |
| 22kΩ | 1 | R1 |
| 100kΩ | 2 | R3, 24 |
| 820kΩ | 1 | R28 |

*Midget Potentiometer*

| | | |
|---|---|---|
| 5kΩ | 1 | R23 |

*[redacted] pre-set*

| | | |
|---|---|---|
| 1kΩ | 1 | R32 |

*Horizontal pre-set*

| | | |
|---|---|---|
| 10kΩ | 1 | R22 |

**Capacitors**

*Monolithic Ceramics*

| | | |
|---|---|---|
| 1nF | 2 | C22, 32 |
| 10nF | 6 | C9, 10, 12, 23, 30, 31 |
| 0·1µF | 7 | C6, 8, 13-15, 19, 29 |

*Polystyrene*

| | | |
|---|---|---|
| 27pF | 1 | C7 |
| 1nF | 1 | C3 |
| 2·2nF | 2 | C4, 5 |

*Electrolytic (axial)*

| | | |
|---|---|---|
| 4·7µF 16V | 1 | C33 |
| 10µF 25V | 3 | C25, 27, 28 |

*Electrolytic (p.c.b. mounting)*

| | | |
|---|---|---|
| 2·2µF 16V | 2 | C24, 26 |
| 100µF 25V | 1 | C20 |

*Miniature Layer Polyester*

| | | |
|---|---|---|
| 0·1µF | 4 | C11, 16-18 |

*Miniature Trimmer*

| | | |
|---|---|---|
| 3-30pF | 1 | C2 |

*Air-spaced Variable*

| | | |
|---|---|---|
| 100pF 2 gang | 1 | C1 |
| 365pF | 1 | C21 |

**Semiconductors**

*Diodes*

| | | |
|---|---|---|
| BZY88 | 1 | D2 |
| IN4001 | 2 | D4, 5 |
| IN4148 | 2 | D1, 3 |

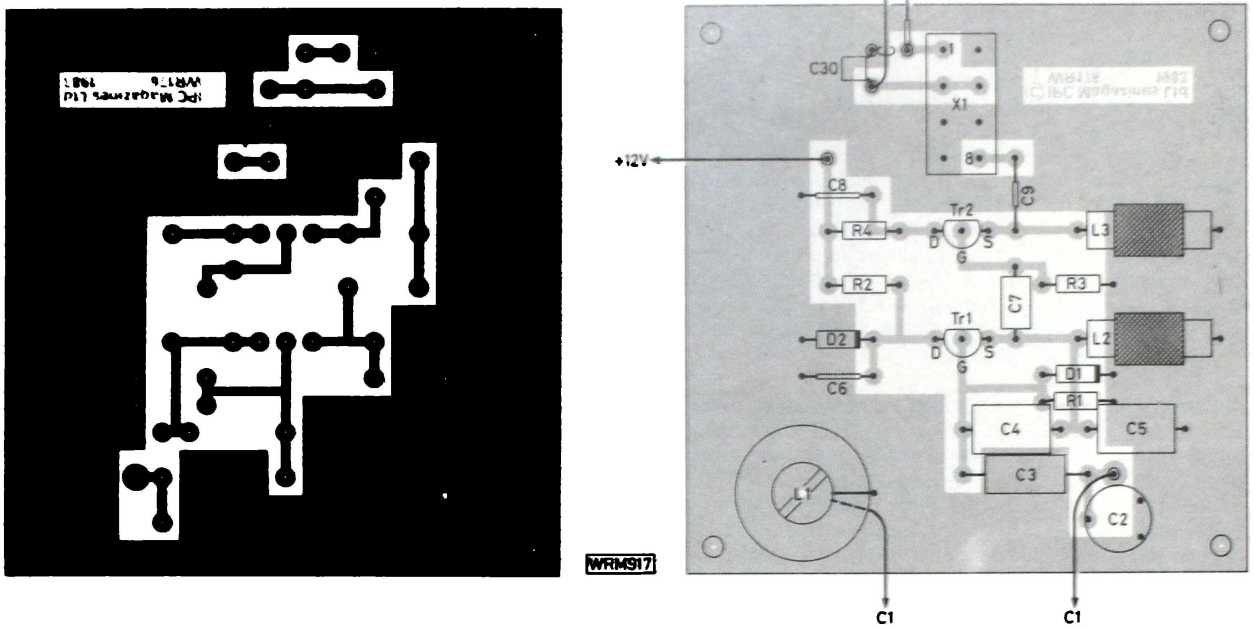
*Transistors*

| | | |
|---|---|---|
| BC107 | 2 | Tr7, 8 |
| BC108 | 1 | Tr3 |
| BC212L | 2 | Tr9, 10 |
| ZN3053 | 3 | Tr4-6 |
| ZN3819 | 2 | Tr1, 2 |

**Miscellaneous**

p.c.bs; s.p.d.t. miniature toggle switch (2); 4p·3w wafer switch; 12V 2 pole changeover relay 185Ω coil; 1·5mH r.f. choke (3); ferrite beads (2); T68-2 torroids (2); SBL-1 double balanced mixer; 200µA moving coil meter (see text); 6:1 slow motion tuning control; 32 s.w.g. & 28 s.w.g. enamelled copper wire; case (see text).

**Fig. 2: Full size p.c.b. track pattern and component placement of the v.f.o./mixer board**




meter should read zero. So an external a.t.u. can be adjusted to obtain this match. This form of bridge is especially useful since even with a severe mismatch the transmitter output is always loaded by R18 and R20 which should be enough to stop the output transistors curling up their toes.

The tuning-up procedure is simplicity itself. The switch, S1, is placed in the SET position where it acts as an r.f. indicator. Capacitor C21 can then be adjusted for peak reading. The switch is then turned to the REF position where it acts as the resistive bridge. The external a.t.u. can then be adjusted for the minimum reading on the meter. The transmitter should now be matched and S1 can be moved to the OUT position which cuts out the resistive bridge and allows all the r.f. into the antenna. It is possible to tune up very quickly using this three step procedure without risk to the p.a. stages and only radiating a very low signal.

## Construction

Most of the transmitter is built on three small boards; a v.f.o. Mixer Board, a Power Amplifier Board and an Audio/Changeover Board.

The v.f.o./Mixer Board is mounted in a small screened box within the body of the transmitter. The prototype used a diecast aluminium box 114 × 89 × 51mm in size, although any sturdy box would serve the purpose. Some constructors seem to have problems with stability in the v.f.o.s. In practice I have found that if a v.f.o. is built to be dropped from 9000m, it will probably be stable! The tuned circuit uses a toroid former which although not favoured by some for v.f.o. tuned circuits, seems to be very stable at this sort of frequency. Capacitor C1 should be a good air-spaced capacitor of some 100pF, these can be very expensive though can be found on the surplus market, (but can't everything). In fact a value slightly over 100pF would be useful as with this value the v.f.o. barely covers the whole of the band. Capacitor C2, a semi-airspaced variable trimmer, sets the band edges. The critical fixed components are the capacitors C3, 4 and 5, these should be high quality temperature stable components. The prototype used polystyrene types but good quality silvered mica capacitors would also be suitable.

One of the problems of a simple d.s.b.s.c. transmitter is v.f.o. leakage through the mixer giving an unacceptable carrier level before the audio signal is applied. Short leads around the SBL-1 mixer, with good screening, are required. The SBL-1 is mounted on the v.f.o. printed circuit board within the v.f.o. case and the circuit board has a large copper ground mat around the mixer module as shown in Fig. 2. The filter capacitor, C30, although shown as part of the Audio Amplifier board in Fig. 1, is mounted as close as possible to the audio input port, pins 4 and 5, of the SBL-1. The mixer output capacitor, C10, is not board mounted but forms the connection between the output port of the SBL-1 on the printed board and a lead-through to take the signal out of the v.f.o. enclosure. The input and output leads to the mixer are all screened cables.

The tuning coil in the v.f.o., L1, is wound on a T68-2 toroidal core, and this core should be physically secure. The coil is 45 turns of 28 s.w.g. enamelled copper wire. The prototype was mounted onto the p.c.b. with a plastics 0BA bolt and held above the board with a large plastics pillar. The tuning requires some form of slow motion drive; the inexpensive little 6:1 epicyclic drives seem suitable for this application. They are easy to use, reasonably smooth, and a circular scale made of metal or stiff card can be mounted onto the portion of the reduction shaft in front of the main gearing. It is wise to build the v.f.o. first and test it in its own right, if only by listening for it on a receiver.

Part 2 of this article will deal with the audio amplifier/changeover board and p.a. board.

Readers who intend to operate the *PW* Dart should be in possession of the appropriate licence issued by the Department of Trade and Industry to those who have passed the City and Guilds Radio Amateurs' Examination. Details may be obtained from: The Department of Trade & Industry, Radio Regulatory Department, Amateur Licensing Section, Waterloo Bridge House, Waterloo Road, London SE1 8UA.

# PW DART QRP TOP BAND TRANSMITTER

## by Rev G.C. Dobbs G3RJV & Colin Turner G3VTT PART 2

**Following on from the general description and details of the v.f.o./mixer board given in Part 1 this concluding part covers the remaining two boards and setting-up details.**

The layout for the Amplifier/Changeover Board is shown in Fig. 3. The audio gain control, R23, is mounted on the back of the case because once set it rarely requires readjustment. The whole amplifier is very simple and can be tested with a pair of headphones on the output when it is built. The same board carries the changeover circuitry including the voltage source for unbalancing the mixer for c.w. operation.

The changeover relay is a small 12 volt double-pole-changeover type. As there are several suitable types all with differing conections a space has been left on top of the p.c.b. to stick the relay by its casing with glue or

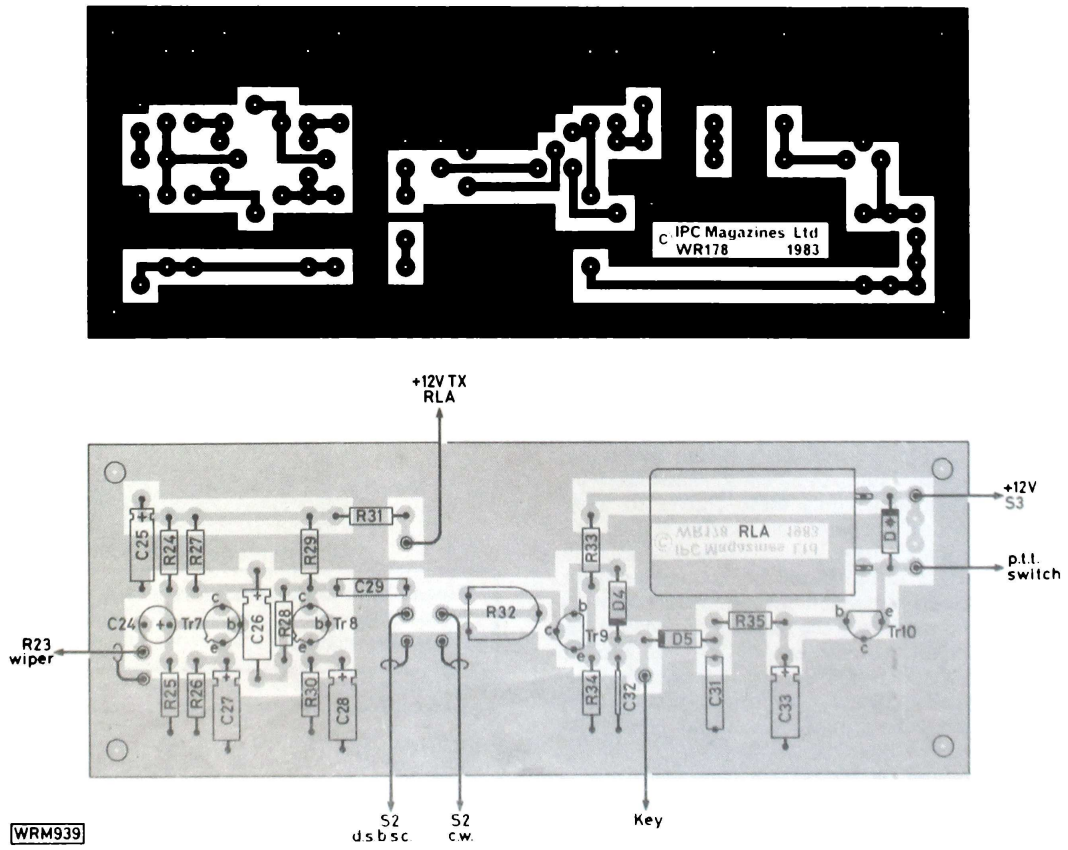



**Fig. 3: Full size p.c.b. track pattern and component placement details of the combined audio processing/changeover board. D* is a 1N4001 and is provided to block back e.m.f. generated by RLA**

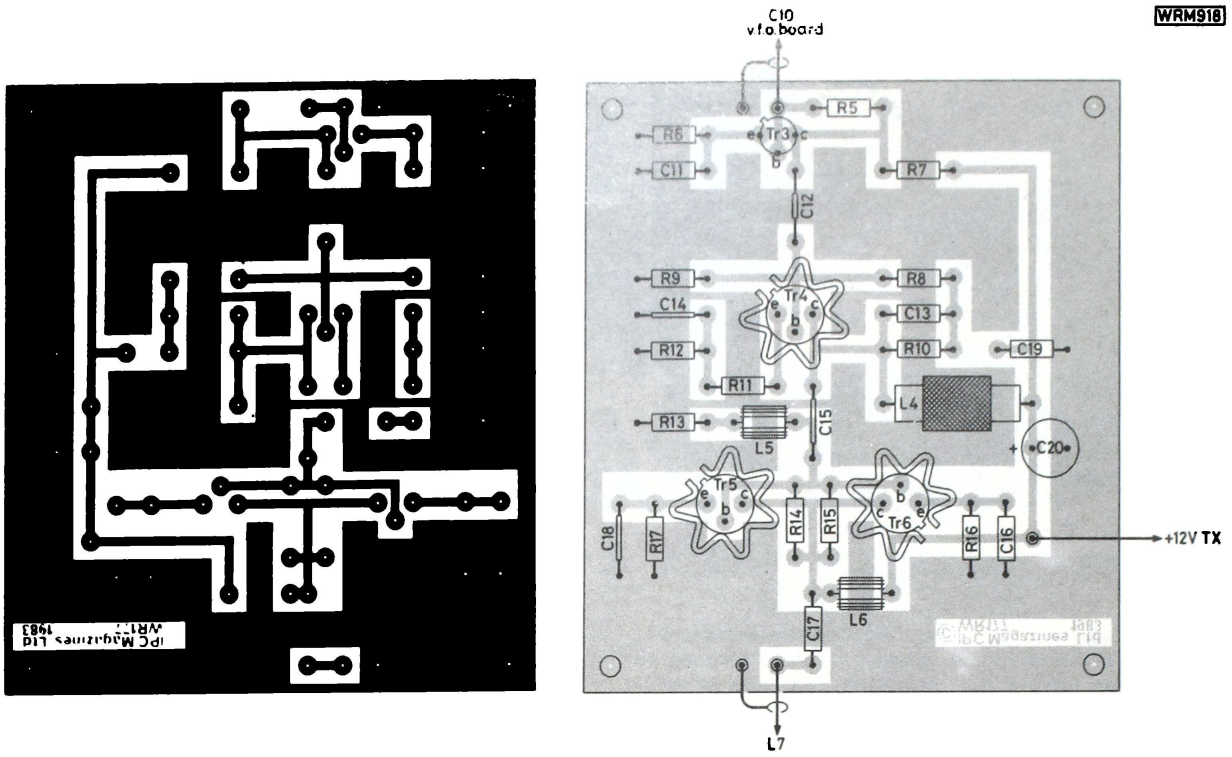



**Fig. 4: Component placement and p.c.b. track pattern details of the p.a. stage, shown full size**

Blutack. The changeover circuit provides the required supplies on transmit and receive for the various sections of the circuit as well as switching the antenna input between the transmitter output and a socket which leads to the receiver. The signal leads should be screened cable.

This board when built can be tested in conjunction with the v.f.o./Mixer module by connecting a receiver to the output of C10. Monitoring the signal on headphones, it should be possible to obtain d.s.b.s.c. signals with S2 in the d.s.b.s.c. position, and then in the c.w. position increase the voltage output from R32 until a c.w. signal can be keyed. Check the action of the changeover. The relay should hold in between words at the normal c.w. keying speed of the operator. If the action is too fast C33 may be increased to hold RLA on longer in keying spaces.

The p.a. Board, shown in Fig. 4 is simple to build although the spacing around the two output transistors is a little tight when the star type heatsinks are added to the transistors. The driver stage, Tr4, also requires a small star type heatsink. Inductors L5 and L6 are both homemade from ferrite beads with 8 turns of 32 s.w.g. enamelled wire. Care must be taken in winding these chokes to avoid scraping the enamel off the wire. The winding is a bit of a tight fit but in the past I have got 12 turns onto a ferrite bead with care, so 8 turns should be no real problem. Capacitor C21 is a front panel control and the prototype had L7 mounted on the side of the back set of vanes of this capacitor. Inductor L7, which is wound on a T68-2 toroid comprising identical 10 turn 28 s.w.g. link windings (a) and (c) wound over the 28 s.w.g. 50 turn resonant section (b), can be attached to a piece of plastic board; the prototype used a matrix board called "Perfboard" which is like Veroboard without the copper tracks. Capacitor C21 is any reasonable sized two-gang 365pF variable capacitor with both gangs wired in parallel. Screened leads take the signal to and from the C21/L7 circuitry.

The whole of the circuit of the resistive s.w.r. bridge is contained on the back of the switch, S1, and the panel meter, M1. The layout of the components on the back of the switch with some spare contacts used for interconnection tags is shown in Fig. 5. Resistor R22 is soldered directly onto the back of the meter. The prototype uses a miniature edgewise meter of some 200μA full scale deflection but almost any moving coil meter with a full scale deflection of 1mA or less can be used. Screened leads are

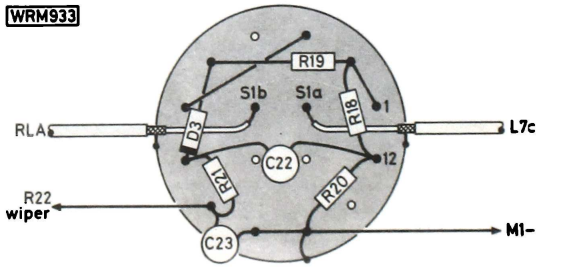



**Fig. 5: Details of the s.w.r. bridge which is mounted on wafer switch S1**

**Please note that transistors Tr4-6, Tr1, 2 should have 2N prefixes and not ZN as shown in the components list.**

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used in the connection to and from the s.w.r. bridge. This bridge is a very compact and useful little circuit which I have used on a whole variety of QRP transmitters.

## Receive Offset

The v.f.o. is left running the whole time to aid stability. The prototype v.f.o. was very stable after the usual movement caused by junction warm up in an f.e.t. oscillator. This means that if the transmitter is switched on to receive there could be some v.f.o. present on the received signal due to leakage through the mixer. In the prototype this was of such low order as to present no problem. If it is a problem the easiest way to deal with it is to offset the frequency of the v.f.o. during receive. This takes the v.f.o. out of the passband of the receiver so that no signal from the v.f.o. is heard on receive. A suitable circuit for this is shown in Fig. 6. A capacitor and a diode form a capacitive circuit across the v.f.o. tuned circuit. On receive 12 volts is applied to this circuit and the capacitance shift should take

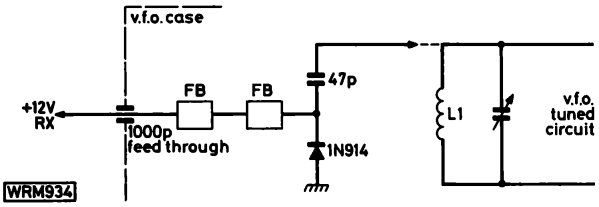


**Fig. 6: Circuit details of the optional receive offset circuit which if fitted must be mounted within the v.f.o. housing in close proximity to the main tuned circuit**

the v.f.o. out of the passband of the receiver. The values shown should do the job but the capacitor may require some adjustment in value to suit individual versions of the v.f.o. This capacitor should be a silver mica type and the additional circuitry added to the v.f.o. must be solid and directly wired to maintain stability.

## Transmitter Netting

If the v.f.o. leakage through the mixer is small—as it should be—then it is difficult to net the transmitter without putting it on to transmit. This is undesirable as some means of locating the transmitter frequency on the receiver, without transmitting, is required to avoid one being a nuisance to other operators. This is quite simple to do by putting S2 into the c.w. mode and pressing the press to talk (p.t.t.) switch on the microphone. This switches on the p.a. without allowing a full signal to reach the output giving plenty of signal to locate the frequency of the transmitter.

The *PW* Dart transmitter represents about the simplest way to put a phone signal onto an amateur band. The tuning-up procedure is simple using the three positions of S1. Resistor R23 should be set to give just enough injection to the mixer to produce a reasonable carrier signal on key down. Reports on the air suggest that most people with s.s.b. transceivers or good receivers think that it is a single sideband suppressed carrier signal. Not bad for a few cheap and standard components. ●

1) *SPRAT, Journal of the G-QRP Club* (Autumn 1981).


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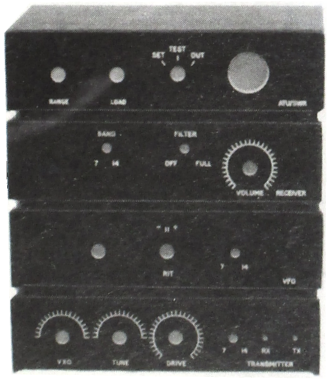

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3.5mm Stereo black plastic . . . . . 22p
3.3mm Mono metal . . . . . 25p
2.5mm Mono plastic . . . . . 20p
2.5mm Mono metal . . . . . 25p

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# FOLLOW UP

by Ken Buck

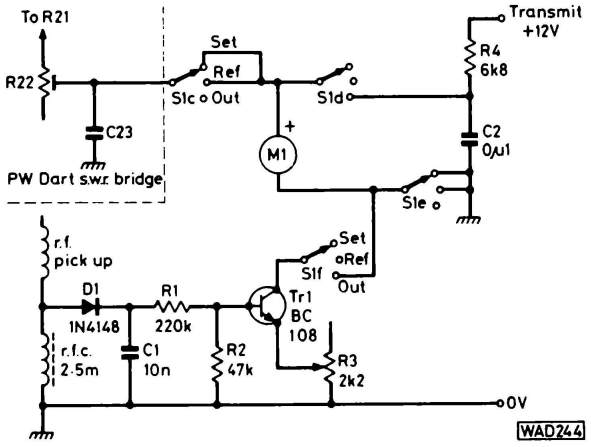
The author found the v.f.o. coverage on the PW "Dart" to be inadequate with L1, C1 and C3 in the original circuit diagram and could only be moved up and down the band with C2. An attempt was made to expand the frequency coverage using the 100pF tuning capacitor with disappointing results.

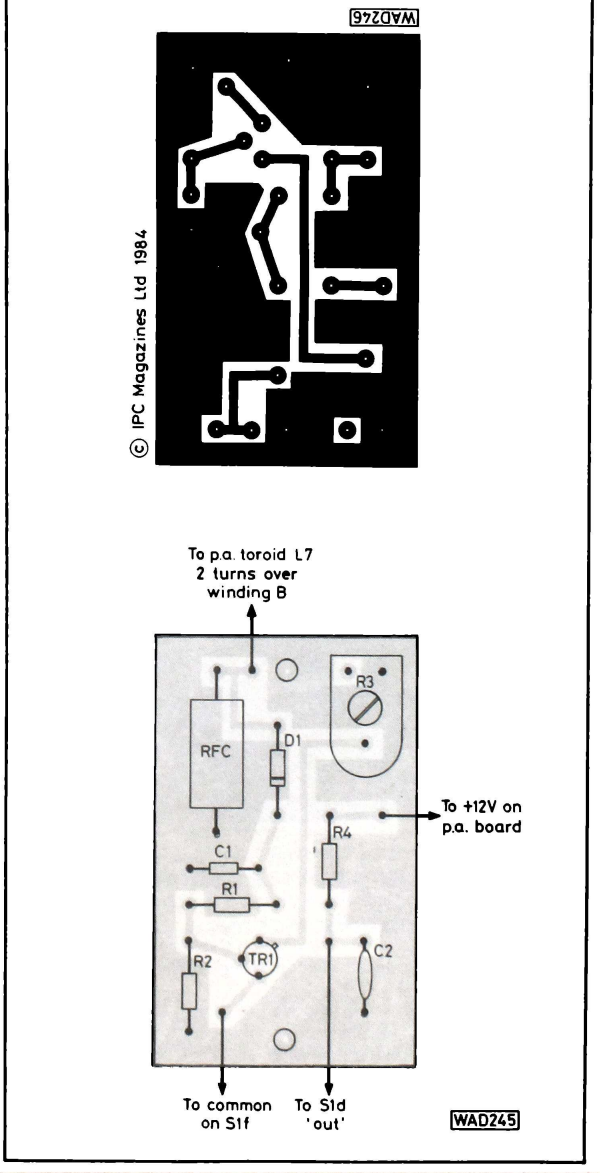
Many amateurs frown upon toroids in v.f.o.s but it was quite stable, however the author decided to discard the toroidal inductor and the 100pF tuning capacitor. A conventional inductor together with a 150pF tuning capacitor gave full coverage of the 1·8MHz (160m) band with a generous overlap at each end. Further tests with the toroid were still unsatisfactory. Inductor L1 is now 75 close-wound turns of 28 s.w.g. enamelled copper wire on a $\frac{1}{4}$in. Aladdin type former, the winding length is 26mm. The windings were sprayed with aerosol lacquer on completion. Formers available in the electronics mail order catalogues are too short and a suitable one was salvaged from a scrap dual-standard television chassis. A tuning core is not required and this will aid the general stability of the v.f.o., C3 was still required in series with C1 and C2.

Capacitor C2 was nearly at maximum capacitance after setting the band edges, so this component should be changed from 3-30pF to 3-90pF. The problem here being that the pin spacing may be different. Inductor L1 should be connected to C1 and the p.c.b. with a single length of 16 s.w.g. copper wire using as short a path as possible.

The two lugs of C1 fixed vanes need to be bridged and substantially soldered. A small hole was drilled at the top front of L1 former and the 16 s.w.g. wire end was stuck into this using an epoxy resin. Calibration of the v.f.o. tuning scale should be carried out last on completion of the transmitter with the p.a. running into a 50Ω dummy load.

The d.c. input to Tr5 and Tr6 is not measured in the usual manner because of the keyed d.c. supply from R32 unbalancing X1 on c.w. An add-on circuit was developed



to simulate p.a. d.c. input which I have called an **r.f. Meter Monitor.** It is a variation of another G3RJV circuit [1] which consists of a diode detector and a single transistor d.c. amplifier. The meter did not give a full scale deflection without this extra amplification.

The meter switching arrangement is quite straight forward, but the original switch had insufficient contacts. A suitable one with two wafers was obtained very cheaply from a surplus stall at a rally and the s.w.r. bridge was rebuilt onto this switch. Two turns of 28 s.w.g. enamelled copper wire overwound at the start and finish of winding B gave sufficient link coupled r.f. input to the meter monitor. All four windings on the p.a. toroid should be secured with spots of glue. Components on the monitor p.c.b. should be mounted low as the board was fitted in the space behind the wafer switch with the r.f. choke close to the toroid. A small board was etched for this toroid and it was then mounted vertically by two solder pins at the edge of p.a. board in front of Tr6. Before testing the meter monitor, ensure the transmitter supply is 12 volts and plug in a 50Ω dummy load to the transmitter antenna socket. With S1 in the SET position and S2 in the CW position, short the key contacts. Adjust C21 for maximum meter reading, turn S1 to OUT and trim R3 for meter full scale deflection. Resistors R1 and R4 may require adjusting for meter movements greater than 200μA, all that is required is the meter to read full scale deflection on key down. The monitor can also be used to verify maximum output when transmitting without having to turn S1 back to SET. It will give the setting for R32 on control board as the variable voltage adjusts the carrier level output from port 3 of X1. A net switch on the cabinet front panel will be useful to c.w. only operators, as the plugging in of a microphone with p.t.t. will be inconvenient. The addition of tuning scale and meter illumination with T-1½-20mA bulbs, and l.e.d. indicators for transmit and receive make the PW "Dart" an ideal starter project for the newly licensed amateur. A visit to one of the rallies will yield many of the components at a considerable saving. ●

1) *A Perf Dipper.* G3RJV. *Shortwave Magazine* August 1982

## ★components

**Resistors**

*¼W 5% Carbon film*

| | | |
|---|---|---|
| 6·8kΩ | 1 | R4 |
| 47kΩ | 1 | R2 |
| 220kΩ | 1 | R1 |

*Horizontal skeleton preset*

| | | |
|---|---|---|
| 2·2kΩ | 1 | R3 |

**Capacitors**

*Monolithic*

| | | |
|---|---|---|
| 10nF | 1 | C1 |
| 0·1μF | 1 | C2 |

**Semiconductors**

*Diodes*

| | | |
|---|---|---|
| 1N4148 | 1 | D1 |

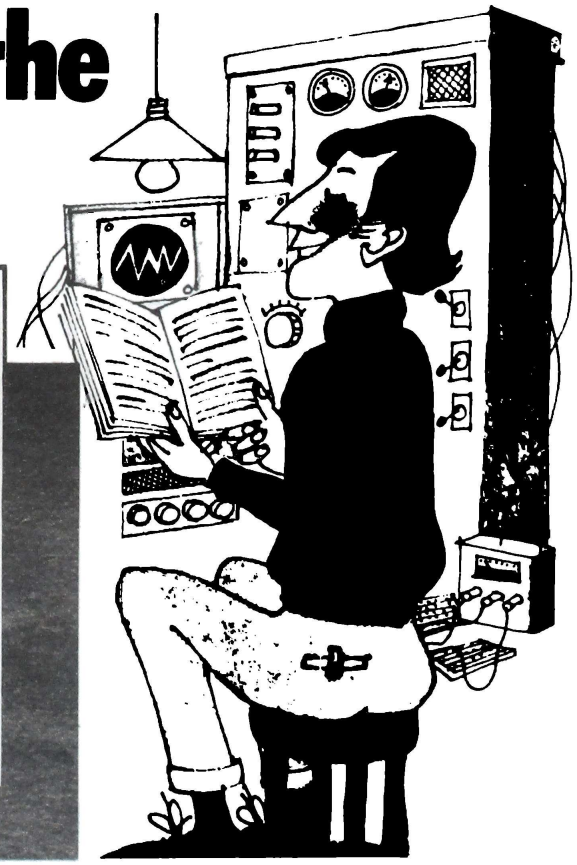
*Transistors*

| | | |
|---|---|---|
| BC108 | 1 | Tr1 |

**Miscellaneous**

Printed circuit board; 2·5mH r.f. choke; 6p 3w wafer switch


# Every month is the right frequency



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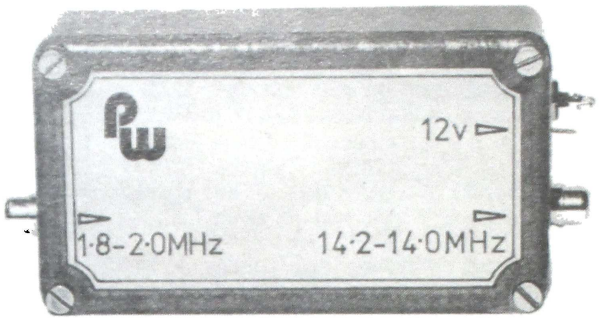



# PW DART TOP BAND CONVERTER

## by Rev G.C. Dobbs G3RJV & Colin Turner G3VTT

The *PW* Dart d.s.b.s.c./c.w. transmitter described in the November and December 1983 issues provides an ideal way to get onto the 1·81–2·0MHz amateur band at little cost. The circuit is perhaps most appealing to those who do not have facilities for that band. Many recent transceivers have omitted "Top Band" so the *PW* Dart, in conjunction with a suitable receiver, can fill in that gap.

It may be that if Top Band is missing from a station transceiver the station could have no receiving facilities for the band. An obvious way to overcome this problem is to build a receive converter to enable the band to be received on one of the more common amateur bands. What follows in this article is a simple up-converter design which can be bolted onto the back of the *PW* Dart transmitter to enable it to be used in conjunction with a transceiver or receiver which can tune 14MHz, to provide full transceiver facilities for the complete 1·8 to 2·0MHz band. The converter could be built as a small project in its own right to enable Top Band coverage to be added to any station receiver that tunes 14MHz.

## Choice of IF

There are a few obvious problems in converting a signal from Top Band to another amateur band. For a start 1·8MHz is uncomfortably near to the medium wave a.m. broadcast band, with a variety of strong stations all waiting to break through on the input. Then there is the problem of breakthrough from existing signals on the amateur band selected as the conversion frequency.

On a dusty back shelf in my shack I have a converter from some years ago built to give me Top Band capability using the 7MHz band as the conversion band. A friendly little unit because if things are quiet on Top Band I can always listen to the local medium wave commercial station or to one of the broadcast stations encroaching into the 7MHz band in the evenings. Plainly a circuit to be avoided!

Another problem is finding a suitable crystal to form the local oscillator (l.o.) frequency for the conversion. Crystals can be etched to order on any suitable frequency but the cost is considerable and rather detracts from the inexpensive approach used in the *PW* Dart transmitter. A prototype was attempted using 27MHz radio control crystals, converting the band up to 29MHz. This works quite well but many receivers can be insensitive at these higher frequencies. The final conversion frequency was decided after noticing an advertisement in the back of *PW* from P. R. Golledge Electronics for "off the shelf" 16MHz fundamental crystals at £3.35 including VAT and postage.

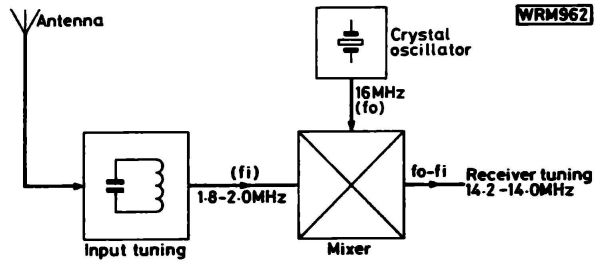



**Fig. 1: Block schematic of the *PW* Dart 1·8MHz receive converter**

## Circuit Design

The approach adopted is shown in block form in Fig. 1. This is the classical simple receive conversion circuit. The required band (1·81 to 2·0MHz in Region 1) is tuned at the input and fed into a mixer stage. A 16MHz crystal provides the frequency for the local oscillator, which is also fed into the mixer. The frequency required at the output is the input frequency (fi) minus the oscillator frequency (fo). This produces the conversion from 1·8 to 2·0MHz as 14·2 to 14·0MHz—reverse tuned on the 14MHz amateur band. The s.s.b. stations on Top Band would normally use the opposite sideband to those on the 14MHz band so the reverse tuning is quite useful in that the sideband switch can be used in its "normal" (u.s.b.) position.

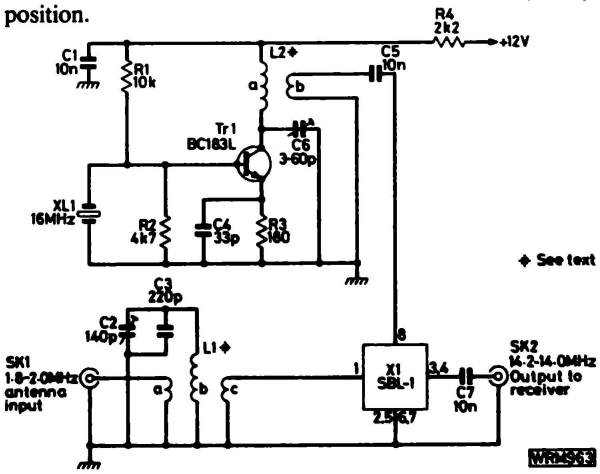



**Fig. 2: Complete circuit diagram of the converter which will provide 1·8MHz band coverage when used in conjunction with a 14MHz receiver**



*Reprinted from Practical Wireless, January 1984*

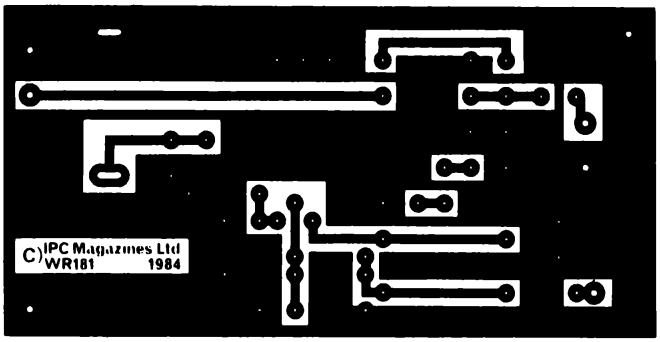
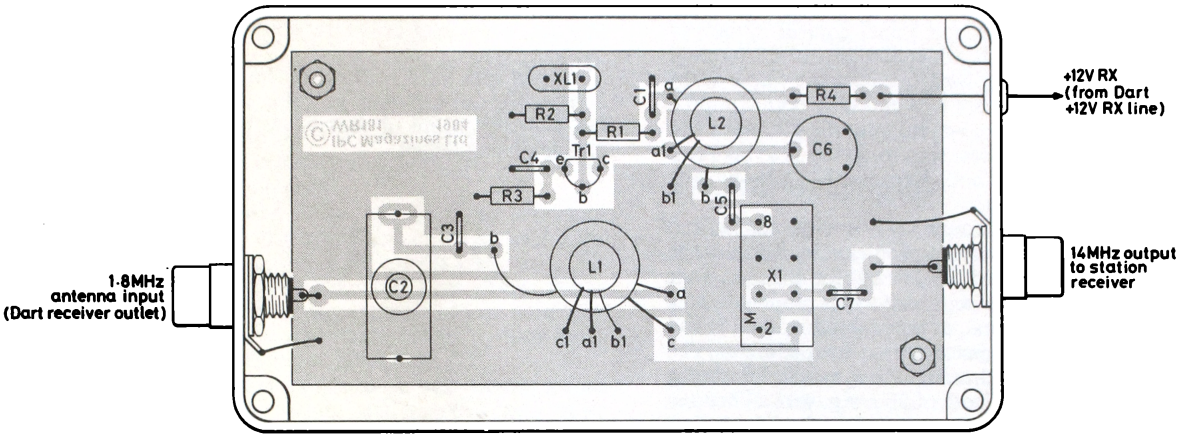



**Fig. 3: Full size p.c.b. and component placement details. Pin 2 of the mixer X1 is located beneath the letter M of the part identification**




## ★ components

**Resistors**
*Carbon film ¼W 5%*

| | | |
|---|---|---|
| 180Ω | 1 | R3 |
| 2·2kΩ | 1 | R4 |
| 4·7kΩ | 1 | R2 |
| 10kΩ | 1 | R1 |

**Capacitors**
*Miniature Plate Ceramic*

| | | |
|---|---|---|
| 33pF | 1 | C4 |
| 220pF | 1 | C3 |
| 10nF | 1 | C5 |

*Miniature Ceramic*

| | | |
|---|---|---|
| 10nF | 2 | C1,C7 |

*Compression Trimmer*

| | | |
|---|---|---|
| 140pF | 1 | C2 |

*Miniature Film Trimmer*

| | | |
|---|---|---|
| 3–60pF | 1 | C6 |

**Semiconductors**
*Transistors*

| | | |
|---|---|---|
| BC183L | 1 | Tr1 |

**Miscellaneous**
SBL-1, double balanced mixer (1); 16MHz crystal HC18/U; phono sockets (2); feedthrough capacitor (see text); diecast aluminium box 110 x 60 x 30mm (see buying box); p.c.b.; T-50-2 toroid (1); T-50-6 toroid (1)

The full circuit diagram is shown in Fig. 2. Like the *PW* Dart, the circuitry is very simple. The mixing is done using a double balanced mixer type SBL-1. This is not a cheap device but it offers obvious advantages in this simple circuit. Being a high level mixer problems with cross modulation and adjacent channel interference are minimised. So much so that one preset tuned circuit ahead of the mixer was found to be sufficient against the ravages of the evening a.m. stations close to 1·8MHz. The balancing within the device is very "tight" and if adequate screening is used

## BUYING GUIDE

Components for this project are readily available. An alternative housing is the Minfordd A8 box. The prototype used a 16MHz HC18/U crystal from P.R. Golledge Electronics.

**Approximate Cost** £15

**Construction Rating** INTERMEDIATE

between the input and output ports and the l.o. the susceptibility to spurious signals is very low. Originally a tuned circuit or filter for the output was considered but in practice this made no difference. The output port is a well matched 50 ohms which can be fed directly, via C7, into the input of a receiver on 14MHz. The SBL-1 is a passive mixer so there is no conversion gain but on Top Band front end gain is of little importance. Who wants to amplify a lot of noise!

The input tuned circuit around L1 was found to be sufficient for the needs of the circuit. A two stage filter was considered, as was an externally adjustable input filter but this simple arrangement works well without problems of adjacent channel breakthrough. Setting C2 to peak signals in the centre of the band serves well for the whole band without need for retrimming. However, the fastidious could make C2 into a variable panel control if they so wish. The winding for L1b, which consists of 63 turns of 32 s.w.g. enamelled copper wire, occupies the whole of the T-50-2 toroid core. Inductors L1a and L1c, both comprising 5 turns of 26 s.w.g., are wound onto the grounded end of L1b. In practice the easiest way to do this is to take two lengths of wire and wind both L1a and L1c side by side onto the core in one action.

The oscillator circuit around Tr1 is very simple and should fire-up first time without problems. A whole range of transistors might be used for Tr1 but the BC183L is as cheap as most commonly available types. Inductor L2a tunes the 16MHz l.o. signal, in conjunction with C6, and L2b provides a low impedance output for the mixer. The two windings are mounted on a T-50-6 toroid, L2a being 16 turns and L2b 3 turns, both of 26 s.w.g. wire. When the oscillator stage is built it is best tested on its own before connection is made through capacitor C5 to the SBL-1.

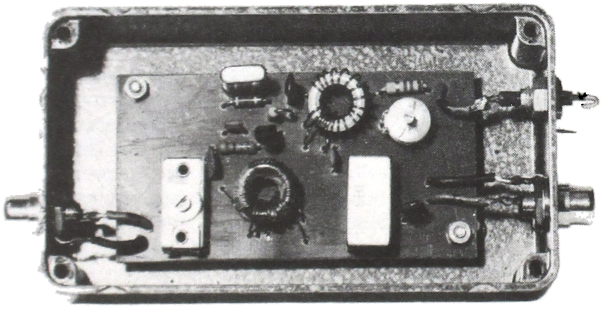


**Fig. 4: A photograph of the author's prototype converter**

A simple r.f. diode probe may be connected onto the output from L2a and a reading taken on a voltmeter. Passive mixers require quite a bit of drive—over half a volt is advised—so the output from L2a should read in the order of 1 to 1·5 volts (peak r.f.). This will be somewhat less when the output is loaded into the SBL-1. Crystal oscillators are perky little things and capable of much higher outputs than required here. If the output is too high, or under 0·5 volts, adjustment can be made to the value of R4.

A single printed circuit board accommodates the complete converter, as shown in Fig. 3. The board retains a large amount of copper to act as a screen mat which helps the isolation between the ports of the SBL-1. All components are standard types and easy to obtain. The assembled board was mounted into a diecast box measuring 110 × 60 × 30mm. This box happened to be to hand but a much cheaper alternative is the Minffordd A8 Box. Either will bolt directly onto the back of the *PW* Dart transmitter case. The input and output terminations are inexpensive phono sockets and a 1nF leadthrough capacitor takes the 12 volt d.c. supply into the box.

## System Connection

The converter is a useful little unit to put ahead of any receiver that lacks Top Band but has 14MHz coverage. If it is to be used with the *PW* Dart, the method of connection is shown in Fig. 3. The Dart changeover board provides for a "receiver" output and a 12 volt d.c. line on receive (12VRX). The receiver line already comes out of the back of the case and can be fed into the converter input. The converter output goes to an existing station receiver on 14MHz. A leadthrough added to the back of the Dart case is probably the best way of getting the 12 volt line to the converter. The converter can now be used with the *PW* Dart and a receiver. Antenna changeover functions are provided within the Dart circuitry so once the converter has been peaked up using C2 it is merely left in place on the back of the transmitter case.

Armed with the *PW* Dart transmitter and this converter it is possible to get onto Top Band at little cost and with the added pleasure of making worthwhile contacts with homebuilt equipment. ●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**Fred Garrett, G4HOM,**
**47 Tilshead Close,**
**Druids Heath,**
**Birmingham B14 5LT.**

# *PW 'Severn'*

# QRP 7MHz Transceiver

## PART 1

Rev. G.C. DOBBS G3RJV

At a time when the main tool of the radio amateur seems to have become the credit card and modern equipment does everything except make tea and give a digital readout of the operator's e.c.g. during a DX pile-up, an interesting development has been the growth of low power (QRP) operation.

For several years now an increasing number of radio amateurs have been working the world using power levels as low as 2 or 3 watts, often with simple home-built equipment and simple wire antennas.

The transmitter power used is not quite the important factor that many would believe. Think of the mathematics. Usually, one 'S Point' on the RST code is taken as a 6dB change and a simple dB/Power chart soon shows that a 6dB increase represents a power increase of four times. So, in theory, increasing a transmitter's power by four times would only give a one 'S Point' advantage.

Amongst QRP operators are those who cannot afford the current prices of h.f. equipment, together with those who simply enjoy the challenge which lower power affords. Many QRP operators have found a new lease of life in what had become a jaded hobby. The great satisfaction when making contacts with low-powered equipment is only surpassed when doing it with equipment made with one's own hands. After all, amateur radio ought not to be merely an equipment user hobby. But be warned, QRP operation, especially with home-made equipment, is addictive. Many radio amateurs with commercial equipment, building little QRP rigs, have found that their expensive grey boxes lie on the bench unused and gathering dust.

The *PW* 'Severn' represents a suitable introduction for the amateur who wishes to try QRP operation. It is a simple c.w. transceiver for the 7MHz band. Some may consider this an odd band for low power operation with its problems of small size and encroaching broadcast stations, but many QRP operators use the band. It allows contacts with UK and European stations and even the odd DX station and QRP operators can be found gathered around 7030kHz.

The project can be a useful starting point for someone who has never built a complete transceiver before, the circuitry is simple and can be built without specialist test equipment. Anyone with a little constructional experience, an existing receiver, and a multimeter should have little difficulty in getting it to work. The receiver could form a project in its own right, perhaps as a first attempt at building an amateur band receiver. Alternatively, just the transmitter section could be built and used with an existing receiver.

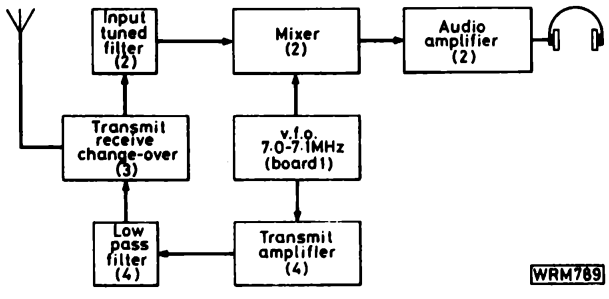



**Fig. 1.1: Block schematic diagram of the *PW* 'Severn'**

## General Description

The *PW* 'Severn' is a direct conversion c.w. transceiver. A block diagram showing the make-up of the receiver is shown in Fig. 1.1. An obvious advantage can be spotted immediately in that a common v.f.o. may be used on the actual frequency of the band.

The principle of the direct conversion receiver has been known for many years, formerly called the Synchrodyne receiver, it has enjoyed a revival during the last few years. The chief merit of such receivers is their simplicity. The more usual superheterodyne receiver converts the incoming signal to an intermediate frequency, where amplification and filtering can take place, then demodulates the signal to recover the original information.

The operation of a direct conversion receiver is to convert the signal directly into audio frequencies where most of the amplification occurs. The top portion of the block diagram shows this action. The incoming signal, after being tuned in the input filter, is fed together with a local oscillator signal into the mixer. The oscillator (v.f.o.) is tuned to the same frequency as the incoming signal. The output of the mixer is decoupled at r.f. to remove the incoming signal and the v.f.o. signal, but the resultant beat notes that appear at the output contain the required information which can then be amplified. In effect, the action is like that of a b.f.o. in a conventional c.w./s.s.b. superhet receiver.

This method of detection means that only c.w. and s.s.b. signals can be resolved, but these are the usual modes of operation on the high-frequency amateur bands.

The receiving process is obviously simplified because only one oscillator is required and the only tuned circuits necessary are those for the signal input. This simplicity may seem to be at the expense of poor sensitivity and selectivity. However, a high gain, low noise, audio amplifier can give good sensitivity and good input tuned circuits and audio filtering can make these simple receivers very selective. My general advice to those who doubt the viability of direct conversion receivers on the amateur bands is to build one. They are simple and inexpensive to build and the results can be quite amazing for the circuitry involved.

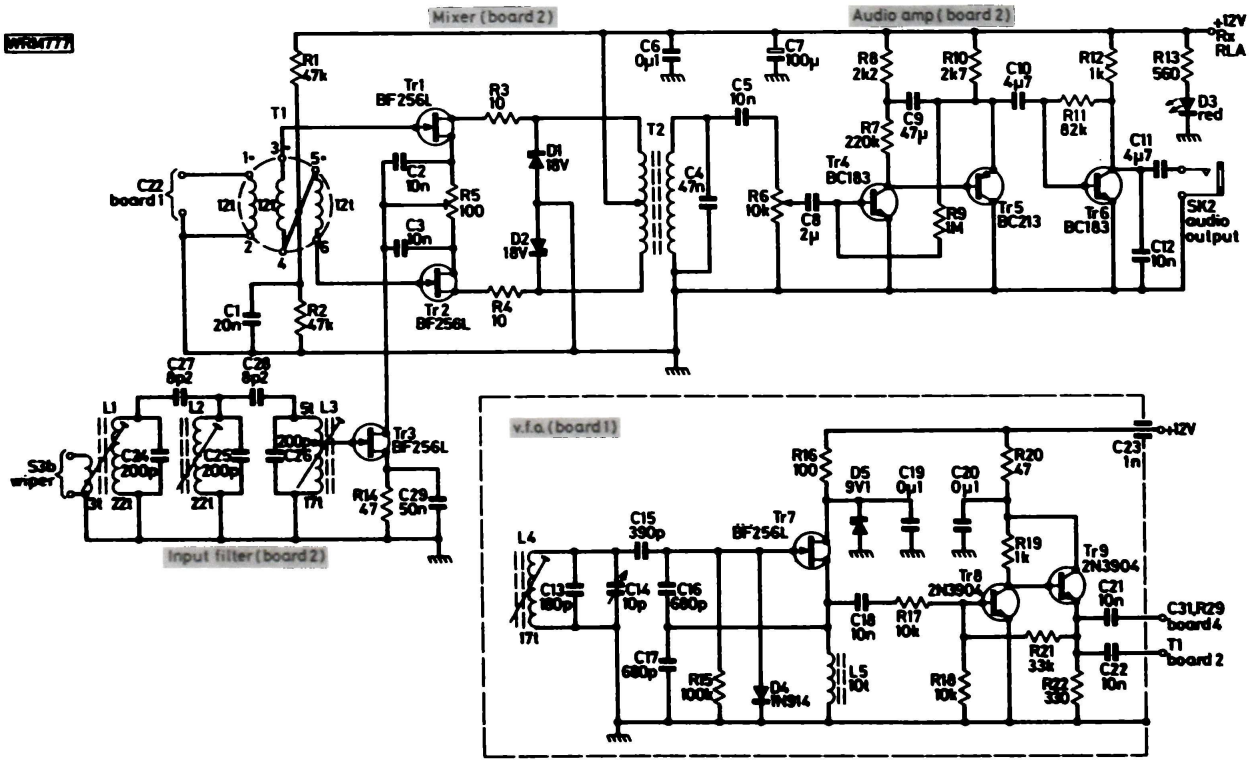
The transmitter portion of the transceiver, shown in the lower part of the block diagram, is simplicity itself. The same v.f.o. is fed into a transmit amplifier board to raise the level to about a couple of watts. The signal is cleaned up in a low pass filter and matched into a 50 ohm

impedance antenna. A transmit/receive change over board directs the signals into and out of the transmitter and receiver at the appropriate times, controlled by the operator's keying, and adds or removes power lines to the various circuit elements as required. The transceiver operates using a semi-break-in technique. That is when the operator begins to key the transmitter comes on and the receive section is switched off. At normal keying speeds this state remains until the keying stops and the transceiver switches back to receive. This operation can be adjusted for various keying speeds and the change-over board also provides a sidetone for the operator to listen to his c.w.

The circuit diagram for the complete receiver including the v.f.o. is shown in Fig. 1.2. The circuits all exhibit standard techniques used for direct conversion reception. For those familiar with the literature on such receivers, and there's a lot of it about . . . as they say, the mixer is perhaps the less usual of all the sections. It is three f.e.t. transistors arranged in a Y configuration similar to that used in many differential amplifier integrated circuits. Tr1 and Tr2 form a balanced mixer and the third f.e.t. in the Y, Tr3, serves as an r.f. amplifier feeding the source connections of Tr1 and Tr2. I originally saw a version of this circuit used by W0YBF in *Ham Radio* Jan. 77 using a twin r.f. j.f.e.t. device for the mixer. This circuit uses two f.e.t.s with a single balancing preset resistor R5. The two Zener diodes, D1 and D2, could perhaps be omitted, but Tr1 and 2 feed their output into a high impedance transformer T2 with lots of turns. Remember the induction coil at school? The high voltage transients generated in T2 might convert the f.e.t. from a mixer into a fast-acting fuse!

The incoming signal is filtered through three tuned stages, L1, 2 and 3, which are loosely top coupled by C27

**Readers who intend to operate the *PW* 'Severn' should be in possession of the appropriate licence issued by the DTI to those who have passed the City and Guilds Radio Amateurs' Examination. Details may be obtained from: The Department of Trade & Industry, Radio Regulatory Department, Amateur Licensing Section, Waterloo Bridge House, Waterloo Road, London SE1 8UA.**



and C28 to give reasonable input selectivity. One or two tuned circuits might be used, but for the sake of a couple of formers and some wire the three stages are an asset. Tr1 and 2 require a balanced input so the v.f.o. signal is supplied via a trifilar wound broadband ferrite transformer, T1, with a 4:1 impedance ratio. If this all seems very technical to the beginner in r.f. construction techniques, do not worry, T1 is simple to wind and proved very uncritical in the prototype receiver.

The audio component from the mixer is transformer coupled, through T2, into the audio amplifier, Tr4, 5 and 6. The audio amplifier is a simple high gain, low noise circuit which has become an evergreen in QRP circles. I first met it in the Ebor Transceiver by G3GWI in *SPRAT, the Journal of the G QRP Club,* and have used it in several receivers since that time. A complementary pair of transistors, Tr4 and 5, feed a simple output stage Tr6. The output is adequate for headphones and the circuit matches into high or medium impedance phones. I have found a whole range of surplus headphones with impedance in the hundreds of ohms which work very well in this circuit. If only low impedance headphones are available they can be used via a transistor output transformer such as the commonly available LT700. For such a simple circuit, this amplifier is ideal in this application.

The v.f.o. circuit is a j.f.e.t. version of the familiar Sieler-type oscillator developed by W2YM (*QST* Dec. 66) and used in many of the circuits which have emerged in recent years in American publications. A full discussion of this type of circuit is presented in *Solid State Design For The Radio Amateur* by the ARRL, a book that every self-respecting radio amateur constructor ought to have on his shelf. Variable frequency oscillators can be the *bete noir* of amateur construction.

The radio construction world often seems beset with tales of woe about v.f.o.s that drift, jump, growl and generally behave in an anti-social manner, but this little circuit rarely seems to give much trouble. Experienced constructors say that the way a v.f.o. is built contributes as much to its success as the type of circuit used and certainly this circuit should be built as firmly as a "brick privy", but more of that next month. The oscillator stage, Tr7, is followed by a two-stage buffer, Tr8 and 9, with two outputs being taken from the emitter of Tr9.

**CONSTRUCTION RATING** Intermediate

## BUYING GUIDE

**Would-be constructors should have no difficulty in obtaining the components for this project. Any specialised components will be dealt with as the series progresses and suitable sources indicated.**

**APPROXIMATE COST** £30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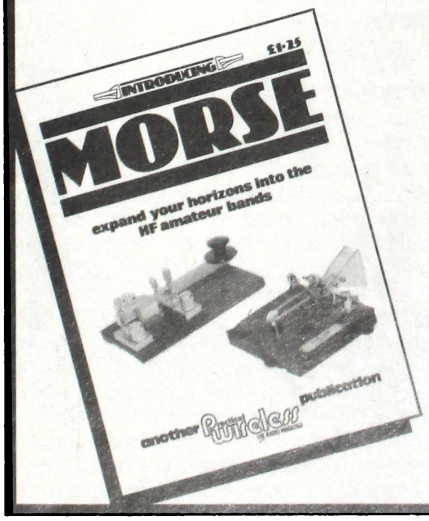


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# PW 'Severn'

# QRP 7MHz Transceiver

PART 2

Rev. G.C. DOBBS G3RJV

## Construction

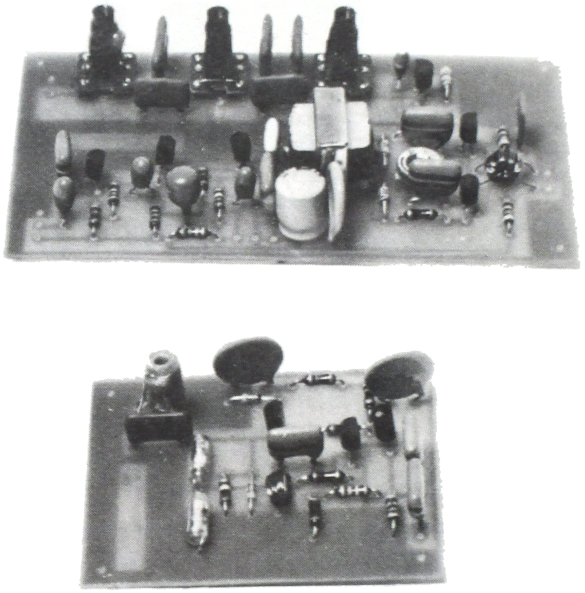
The receiver is built on two printed circuit boards, one for the v.f.o. housed in a screened box and the other for the rest of the circuitry. The v.f.o. Board, shown in Fig. 2.1, is probably best built first and tested in its own right. A few of the components are worthy of mention. The capacitors associated with the frequency determining tuned circuit need to be of good quality. These are C13–17. C14 is the tuning control and should be a good quality, air-spaced variable capacitor with a maximum capacitance of 10 or 15pF.

These can be very expensive and are the sort of component that a seasoned constructor will seek out at junk sales and radio rallies. The thrifty can even saw off a few back vanes of a larger variable capacitor to produce the value which gives an appropriate frequency coverage. C14 is mounted on the front of the box which houses the v.f.o.

The remaining fixed capacitors should either be silver mica or polystyrene types to aid frequency stability. Ideally, some of the circuit padding should be done with NPO type capacitors, but these are often difficult to obtain. In this circuit, as in many others, I have used a mixture of silver mica and polystyrene types. The former usually drift up and the latter down, so a mixture often works out well in practice . . . I hope no one technical reads this magazine!

The Radio Frequency Choke (L5) is home-made from 10 turns of 32 s.w.g. enamelled wire wound onto a ferrite bead. The coil, L4, is wound on a 4·8mm former. These are readily available as surplus items, as practically every piece of r.f. gear built in the '60s and '70s seemed to use this size former. They can also be bought by mail order from Maplin. L4 is cemented into a hole drilled in the printed circuit board. The coil uses an iron dust core (4mm × 10mm) for setting up the correct frequency. There can be a risk of thermal effects in such cores causing drift, but in practice this does not seem to happen if only a small portion of the core is inserted into the winding. With the number of turns advised here that is the case. The windings are best secured by polystyrene cement "borrowed" from your son's modelling kit.

Building and mounting the v.f.o. is critical. Rigidity is the keyword; imagine it being passed along a row of All Black forwards or being a GPO Christmas parcel. It should be mounted in a strong metal box (102 × 64 × 38mm in the prototype) using 6BA bolts on standoffs. The power line enters the box through a 1000pF capacitive feedthrough and the outputs leave via non-capacitive leadthroughs. The tuning control, C14, requires a reduction drive to facilitate ease of tuning. The ideal, and cheapest, solution is to use one of the small in-line epicyclic drives which usually have a reduction of some 6 or 8 to 1. This may be mounted onto the outside of the front of the screened box using standoffs and 6BA bolts. A method of adding a dial will be described later.



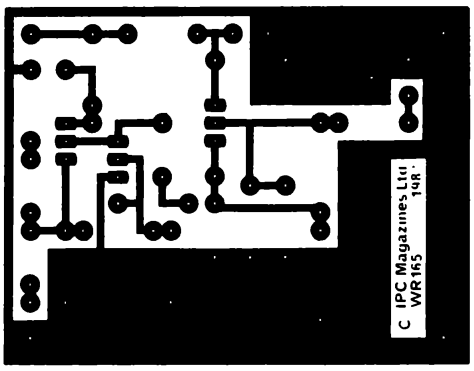
**The two boards described in this part. Top is the receiver and audio board while below it is the v.f.o. board**

When the v.f.o. is completed it can be tested. Those fortunate enough to have access to a digital frequency counter can measure the frequency directly. Another, quite adequate, way is to pick up the output on a receiver. Set C14 fully meshed and adjust the core of L4 to just below 7MHz. A complete 180 degree rotation of C14 should take the v.f.o. just past the top end of the band (7·1MHz). If the desired frequency coverage is not obtained, C13 may be changed in value or turns can be added or removed from L4. However, with the suggested number of turns no such problem should arise. The final adjustment of the frequency is best done with the lid on the screened box, a hole being drilled so that a non-metallic trimming tool can reach the core of L4. Slight drifting when the supply is connected is usual, and is due to the junction of Tr7 reaching a stable operating temperature.

The rest of the receiver is built onto the board shown in Fig. 2.2. The audio amplifier may be built first and tested by injecting a small signal or putting a finger on the input of C8. The audio gain control, R6, is front panel mounted with screened leads between it and the board. Transformer T2 is a transistor audio driver transformer of the type used in push-pull circuits in domestic radios. One suitable type is the LT44 transformer, although it is much cheaper to cull a suitable component from an old transistor radio.



*Reprinted from Practical Wireless, June 1983*



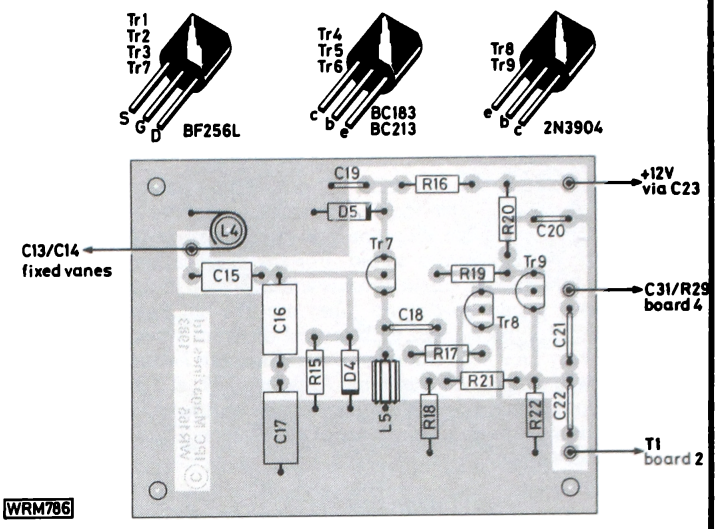
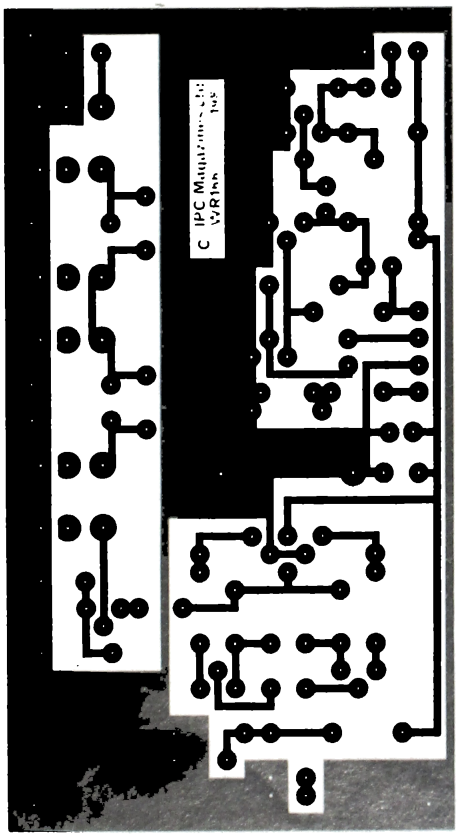




**Fig. 2.1: Copper track pattern and component layout for the v.f.o. board shown full size**



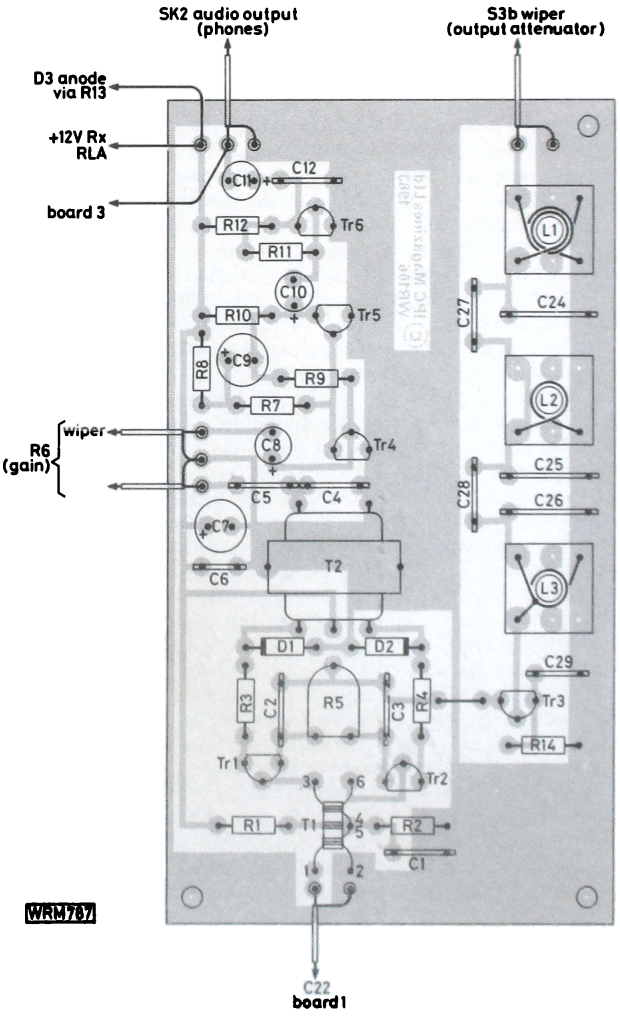




**Fig. 2.2: Copper track pattern and component layout for the main receiver and audio board shown full size**

Usually the ones built in the '60s with the OC family of *pnp* transistors yield a suitable driver transformer. These transformers are commonly a few thousand ohms, centre tapped, into about ten thousand ohms. Three different surplus transformers were tried in the prototype and all worked well.

The trifilar wound transformer, T1, providing a balanced input to the mixer, from the v.f.o., deserves mention. It may look complex, in the diagram, but is very simple to wind. The former is a ferrite toroid. For this application, almost any of the smaller ferrite toroids which pile up in the surplus market would do the job. They are like red Polo Mints. The prototype worked with several different types, including a very nice little toroid of outer diameter 7·6mm and unknown origin. A standard Amidon T37–6 RF Toroid, although dust iron rather than ferrite, also worked well in the circuit. Amidon toroids are available from Cirkit and TMP Electronics.

**Coil winding details**

| Coil | Turns | Wire (s.w.g.) | Former (mm) | Core |
|---|---|---|---|---|
| L1 | 22,3 | 26 | 4·8 | Iron dust |
| L2 | 22 | 26 | 4·8 | Iron dust |
| L3 | 17 + 5 | 26 | 4·8 | Iron dust |
| L4 | 17 | 26 | 4·8 | Iron dust |
| L5 | 10 | 32 | On ferrite bead | |
| T1 | 12,12,12 | 32 | Trifilar wound on toroid | |

The coil T1 has three windings marked as shown, which are twisted together and wound around the core. The dot markings on the diagram, Fig. 1.2, indicate the start of each winding and Fig. 2.2 drawing shows how these three windings are connected together in the circuit. Begin by taking three lengths of wire long enough to make the required 12 turns. These wires are then twisted together, one twist every 3mm is enough, along their whole length, to form one thick wire. Ask your wife what three-ply wool looks like. The turns are wound on the toroid, each pass through the hole representing one turn. Separate the wires and scrape some enamel off the ends of each one. The individual windings can now be identified using a multimeter on the ohms range for a continuity check. The appropriate ends are connected as per the p.c.b. drawing. The winding should be spaced to occupy most of the core.

The input tuned circuit coils L1, 2 and 3 are wound on the 4·8mm diameter coil formers with dust iron cores. The printed circuit layout shows them mounted onto the s.r.b.p. base plates that are common for such formers. Stiff copper wires rise vertically from the base pins and act as solder points for the windings. If the base plates are not available, the formers may be mounted as in the v.f.o. Note that the input tuned circuits are fixed tuned, which is acceptable over the 100kHz excursion of the 7MHz amateur band. L1, 2 and 3 require to be tuned somewhere in the centre of the required coverage. As the transceiver is for c.w. operation only, around 7025kHz is ideal. The prototype was peaked on 7030kHz, the QRP calling channel for Europe. Although the coils may be peaked, using the cores, by listening to signals on the completed receiver, it is an asset to set up the tuned circuits before the receiver is tested. This can be done in a variety of ways, with a g.d.o., a signal generator and some form of output measurement or even by trying the input filter ahead of an existing receiver on the 7MHz band and peaking the signals.

The completed receiver is tested by making the interconnections between the boards. Screened lead, made from thin cable such as RG174 coaxial cable, must be used for all the signal paths. The coverage of the receiver will previously have been checked by measuring the range of the v.f.o. with another receiver or a frequency counter. The other minor adjustments may be done with a signal injected from a signal generator or with signals on the band. The latter approach may sound less technical, but "testing on the hoof" takes a lot of beating. The input coils might require a final peaking and the balance control R5 is adjusted for the optimum output with a weak signal. The prototype receiver proved surprisingly sensitive in use and the final adjustments were made using American c.w. signals on the band.

## Simple Receiver Additions

The 7MHz band is taxing for even the best receiver with its confined space and intruding illegal broadcast stations. As was expected, the receiver suffered from some broadcast breakthrough during certain times of day. The two usual remedies for such problems in direct conversion receivers is input attenuation and audio filtering. A simple potentiometer circuit could be added to the input to provide attenuation, but for the little extra cost a switched attenuator with correct input and output impedance matching is preferable. Attenuating the input to a simple receiver may seem odd. Why reduce the signal when sensitivity is important? In practice, a degree of input attenuation will be survived by all but the weakest signals and greatly reduce cross modulation caused by adjacent spurious signals.

Fig. 2.3 shows a switched input attenuator circuit with steps of −6dB and −12dB; 6dB is usually taken as 1 'S' point on the RST signal coding scale. The circuit will allow, with combinations of switching, 0dB (direct path), −6dB, −12dB and −18dB attenuation. The whole circuit is wired onto the back of two miniature two-way changeover toggle switches. Slide switches can be used for economy but tend to be prone to poor contacts. The input from the antenna and the output to the receiver are routed through screened leads. Simply adding 6dB of attenuation made quite a difference in difficult conditions.

Audio filtering, even of the simplest type, can be a great aid in a direct conversion receiver. The simplest possible audio filter is shown in Fig. 2.4. It consists of a tuned circuit, L6 and C30, resonant at about 750Hz. This peaks audio signals at that frequency at the expense of other frequencies. The coil L6 is a surplus telephone loading inductor of the type usually imported from the USA and in common amateur radio usage. Several component dealers stock such coils which are toroid wound and made up of two 22mH windings which have to be connected together, series aided, to provide 88mH of inductance. The tuned circuit is added across the input of the audio amplifier between the top of R6 and ground. C5 isolates the circuit from T2 but it is damped a little by R6. In practice, this proved no problem and s.s.b. signals can be read very clearly through the filter. Constructors unhappy about the loading effects of R6 can add another 10nF capacitor between the switch (S1) and R6. Screened leads were used between the filter S1 and the circuit board. Closing the switch (S1) brings the filter into circuit. Naturally the constructor could add an active audio filter to the receiver. A variety of circuits and commercial active audio filters could be used either before the amplifier or on the output.

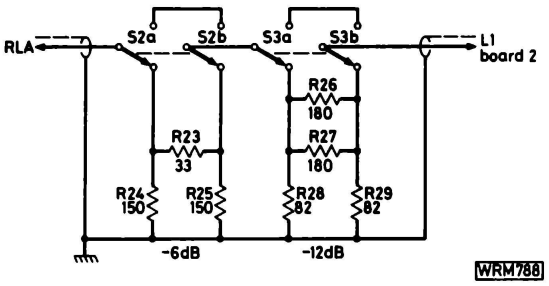
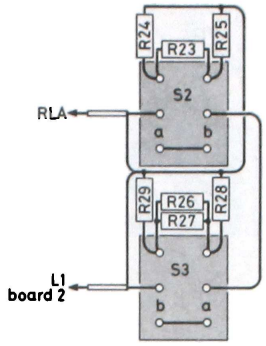



**Fig. 2.3: The circuit and constructional details of the switched input attenuator**



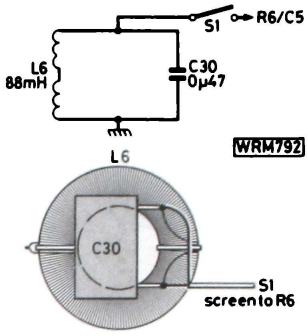




**Fig. 2.4: The circuit and construction of a suitable audio filter**

Quite a lot of the components used in the receiver can be obtained on the surplus market or at radio rallies. Alternative transistor types may be used if these are cheaper. The f.e.t.s used for Tr1, 2 and 3 should be of the specified type, as some surplus types may cause balancing problems in the mixer but Tr7 could be the cheap 2N3819. Tr8 and 9 could be BC108 transistors and a variety of complementary pairs can be used for Tr4, 5 and 6. These include BC318/BC321, BC171/BC251 and BC414/BC416. T2 can be culled from an old transistor radio and surplus ferrite toroids can be used for T1 with all the other coils wound on surplus 4·8mm diameter formers. The 88mH coil, L6, is also a surplus item. Part of the "QRP Philosophy" is about saving money in the hobby. So try to find the components from the cheapest sources. Why not join that exclusive group of radio amateurs who boast about how little their equipment cost rather than how much it costs.

## ★ components

**Resistors**

*Carbon film ¼W 5%*

| | | |
|---|---|---|
| 10Ω | 2 | R3,4 |
| 33Ω | 1 | R23 |
| 47Ω | 2 | R14,20 |
| 82Ω | 2 | R28,29 |
| 100Ω | 1 | R16 |
| 150Ω | 2 | R24,25 |
| 180Ω | 2 | R26,27 |
| 330Ω | 1 | R22 |
| 560Ω | 1 | R13 |
| 1kΩ | 2 | R12,19 |
| 2·2kΩ | 1 | R8 |
| 2·7kΩ | 1 | R10 |
| 10kΩ | 2 | R17,18 |
| 33kΩ | 1 | R21 |
| 47kΩ | 2 | R1,2 |
| 82kΩ | 1 | R11 |
| 100kΩ | 1 | R15 |
| 220kΩ | 1 | R7 |
| 1MΩ | 1 | R9 |

**Potentiometers**

*Min. horizontal preset*

| | | |
|---|---|---|
| 100Ω | 1 | R5 |

*Carbon track ¼inch spindle*

| | | |
|---|---|---|
| 10kΩ (log) | 1 | R6 |

**Semiconductors**

*Diodes*

| | | |
|---|---|---|
| 1N914 | 1 | D4 |
| Red l.e.d. | 1 | D3 |
| BZX61C9V1 | 1 | D5 |
| BZX61C18V | 2 | D1,2 |

*Transistors*

| | | |
|---|---|---|
| BC183 | 2 | Tr4,6 |
| BC213 | 1 | Tr5 |
| BF256L | 4 | Tr1,2,3,7 |
| 2N3904 | 2 | Tr8,9 |

**Capacitors**

*Disc ceramic*

| | | |
|---|---|---|
| 0·1µF | 3 | C6,19,20 |

*Silver mica*

| | | |
|---|---|---|
| 8·2pF | 2 | C27,28 |
| 180pF | 1 | C13 |
| 200pF | 3 | C24,25,26 |

*Polystyrene*

| | | |
|---|---|---|
| 390pF | 1 | C15 |
| 680pF | 2 | C16,17 |

*Polyester*

| | | |
|---|---|---|
| 10nF | 7 | C2,3,5,12,18,21,22 |
| 20nF | 1 | C1 |
| 50nF | 2 | C4,29 |
| 0·47µF | 1 | C30 |

*Tantalum bead*

| | | |
|---|---|---|
| 2µF 35V | 1 | C8 |
| 4·7µF 35V | 2 | C10,11 |
| 47µF 16V | 1 | C9 |

*Electrolytic p.c.b. type*

| | | |
|---|---|---|
| 100µF 16V | 1 | C7 |

*Lead-through*

| | | |
|---|---|---|
| 1nF | 1 | C23 |

*Airspaced variable*

| | | |
|---|---|---|
| 0–10pF | 1 | C14 |

**Miscellaneous**

Min. toggle switch d.p.d.t. (2); Metal box (see text); Ferrite bead (1); 88mH telephone line loading coil (see text); Coil former 4·8mm dia (4); Ferrite toroid (see text); Transistor audio driver transformer (see text); Printed circuit boards (2).

# *PW 'Severn'*
# QRP 7MHz Transceiver

## PART 3

Rev. G.C. DOBBS G3RJV

We have looked at the construction of a direct conversion receiver with a v.f.o. on the 7MHz band. Such receivers have the advantage of being easily convertable to transceivers because the same oscillator can be used to excite the transmitter chain. My general view of transceiver construction is that when the receiver is built and working well . . . "You've cracked it". The addition of the transmit circuitry is simple compared with the task of producing a worthwhile receiver on the amateur bands.

There are many "myths and legends" and not a few hard luck stories about attempting to build a solid state transmitter. Some constructors spend hours studying the theory of r.f. techniques, others build the boards with their fingers crossed—not easy. But no amount of studying, whether it be of the latest learned text or the entrails of a small mammal, can beat finding a tidy little circuit which works well and sticking with it. The circuit I offer for the transmitter section of the *PW* 'Severn' is just that sort of circuit. I have used it in several transmitters and transceivers (such as Ben: The Little Transceiver for 10MHz, *Short Wave Magazine* Jan–Feb, 1982), with success in every case.

The transmit section of the *PW* 'Severn' is genuine QRP in that it runs about 2 watts d.c. input which can be surprisingly effective on the band. The p.a. transistor is uncritical with several types of inexpensive devices offered as alternatives. For the Radio Amateur who wishes to sample QRP operation but use his existing receiver, the transmit board from this section, with the v.f.o. from Part 2, could make a useful first QRP transmitter. A simple method of doing this is discussed at the end of the article. An operator using just a couple of watts of homebrewed r.f. power can command great respect from his fellow amateurs on the band. Why not try it?

## The Transmit Board

The transmit board is shown in Fig. 3.1. It is a three stage tuned power amplifier running some 2 watts d.c. input to the final stage. The pre-driver, Tr10, and driver stage, Tr11 are both keyed in a common 12 volt line. The final amplifier is capacitive coupled, via C38 into a fixed pi-network. This output circuit is something of a compromise but with Tr12 at about 2 watts input the L9/C39/C40 network is near enough to 50 ohms impedance in and out. The network could be tunable but over the 100kHz excursion of the 7MHz band the bandwidth is adequate and the output appeared flat over the whole c.w. section of the band. Several devices could be used for Tr12 and the individual constructor may find access to several reasonably or lowly priced transistors for the p.a. A whole variety of devices were tried in the prototype, perhaps the best being a completely unknown surplus type. Excellent results were had from the following: 2N3553, BLY33, 2N4427 and BSX61. Slightly less output was obtained from: 2N3866, BFY51 and some examples of the 2N3053.

Both the pre-driver and driver stages are operated in Class A. It would be quite possible to use one higher gain stage but this method has several advantages. Less gain per stage seems to ensure stability for the little extra cost involved. The additional linearity is also useful, for although the transmitter is for c.w. a driver run at saturation still appears to behave in a linear fashion for spurious products and all the "nasties" slip through with relative ease. Two lower gain stages which are tuned also make a single pi-network acceptable in the output of the p.a.

The p.c.b. layout and component layout are shown in Fig. 3.4. The board is compact but no problems appeared with this layout. The method of construction was the old faithful of building the board a stage at a time and testing as the work progressed. The only test equipment that is essential is a simple r.f. probe which can be used with a multimeter. The circuit for the r.f. probe is shown in Fig. 3.2. This can be built on a piece of scrap p.c.b. or Veroboard. Ideally, it should be in a screened case although this is not vital if the leads to the meter are screened. The probe may be a short length of stiff copper wire. If the constructor does not already have an r.f. probe it is probably a good idea to spend a little time and build it up as a respectable unit. Such probes can make a very useful addition to any amateur workshop. The probe is

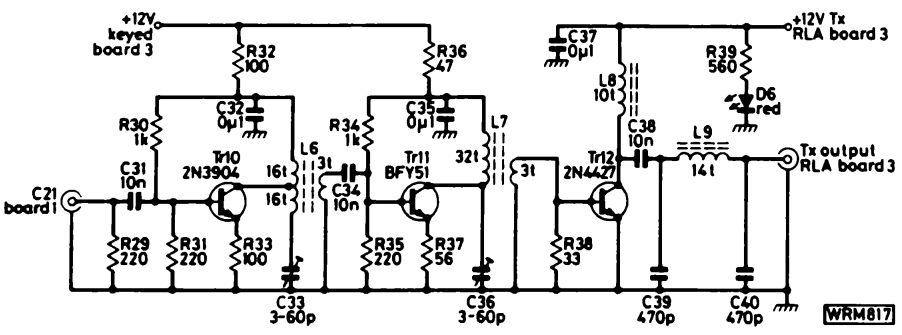



**Fig. 3.1: Circuit diagram of the transmit section of the *PW* 'Severn'**



*Reprinted from Practical Wireless, July 1983*

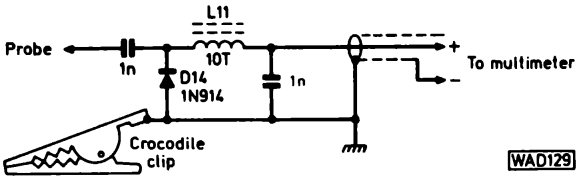



**Fig. 3.2: A simple r.f. probe suitable for use in aligning the transmitter board**

plugged into a multimeter which is then used on a low voltage scale, or in cases of very low r.f. measurements a d.c. current range may be used. The reading is of the peak r.f. voltage present at the probe tip. Lack of screened leads to the meter can give spurious readings through r.f. pickup in the meter leads.

The first stage, Tr10, is built as shown in Fig. 3.4. The output tuned circuit, L6 and C33, should tune the 7MHz band without problems. L6 is wound on an Amidon T50-2 toroid with the main, centre tapped, winding taking up almost the entire length of the toroid. These are available from Cirkit, Park Lane, Broxbourne, Herts EN10 7NQ. Tel: 0992 444111, Tlx: 22478. Although not really variable the inductance of coils wound on toroids can, in practice, be altered a little by opening or closing the spacings between the turns. C33 is a Mullard type semi-airspaced trimmer.

The stage can be tested by running a screened lead from the v.f.o. (Part 2) to the input of the board and applying the 12 volts required for Tr10. The r.f. probe is connected to the output link winding of L6. It should be possible to peak the r.f. output from L6 using the trimmer C33. Tune the v.f.o. to somewhere in the centre of the c.w. sector of the band. If C33 fails to give a peak then the tuned circuit is probably not on frequency and could be amended by altering the number of turns on the main winding of L6. This should not be necessary with the values as given in the Table.

The driver stage, Tr11, is then built and tested as above with the r.f. probe on the output of L7. The p.a. stage is very simple with a homemade r.f. choke providing the collector load. The fastidious could even buy a 100µH r.f. choke. The only critical capacitors in the transmit board are those used in the pi-network. C39 and C40 ought to be good quality silver mica types. There is little point in generating a little decent r.f. to lose it in the output filter. The miniature dipped ceramic capacitors, very attractive though they look, usually give problems even with the small amount of r.f. power used in this type of circuit.

The p.a. stage needs a load on the output before it is tested. Small transistor p.a. stages are not the destructive test beds for devices that some believe, but Tr12 does require a small heatsink and a 50 ohm termination. For test purposes a couple of 1 watt 100 ohm carbon resistors in parallel will do the job. The r.f. probe can then be used to test the output of the whole board. If the constructor has an r.f. power meter which incorporates a 50 ohm load the actual r.f. power can be measured.

There are many myths about the instability found in transistor p.a. circuits. This little board gave no such trouble. Some constructors slip little ferrite beads onto the transistor base lead; not only was that not required for this board but the prototype was built with a bulky transistor holder for Tr12 so that various devices could be tried and it still behaved itself. Note that the p.a. is switched on the whole time during transmit with the driver stages being keyed. If the p.a. gives r.f. output with the driver stages keyed off, then you have got problems . . . I have used this circuit, or ones like it, in several transmitters and found it most forgiving.

## ★ components

**Resistors**

*Carbon Film ¼W 5%*

| | | |
|---|---|---|
| 33Ω | 1 | R38 |
| 47Ω | 1 | R36 |
| 56Ω | 1 | R37 |
| 100Ω | 2 | R32,33 |
| 220Ω | 3 | R29,31,35 |
| 330Ω | 1 | R46 |
| 560Ω | 1 | R39 |
| 820Ω | 1 | R42 |
| 1kΩ | 3 | R30,34,41 |
| 2·2kΩ | 3 | R44,45,49 |
| 3·3kΩ | 1 | R40 |
| 10kΩ | 1 | R47 |
| 82kΩ | 1 | R43 |

**Semiconductors**

*Diodes*

| | | |
|---|---|---|
| 1N914 | 8 | D7,8,9,10,11,12,13,14 |
| Red l.e.d. | 1 | D6 |

*Transistors*

| | | |
|---|---|---|
| BCY71 | 2 | Tr14,15 |
| BFY51 | 2 | Tr11,16 |
| TIS43 | 1 | Tr13 |
| 2N3904 | 1 | Tr10 |
| 2N4427 | 1 | Tr12 |

**Potentiometers**

*Min. Horizontal Presets*

| | | |
|---|---|---|
| 10kΩ | 1 | R48 |

**Capacitors**

*Silver Mica*

| | | |
|---|---|---|
| 25pF | 1 | C48 |
| 47pF | 1 | Fig. 3.7 (see text) |
| 470pF | 2 | C39,40 |

*Polyester*

| | | |
|---|---|---|
| 0·1µF | 6 | C32,35,37,41,42,43 |

*Disc Ceramic*

| | | |
|---|---|---|
| 10nF | 3 | C44,45,46 |

*Tantalum Bead*

| | | |
|---|---|---|
| 68µF 16V | 1 | C47 |

*Feed-through*

| | | |
|---|---|---|
| 1nF | 1 | C49 |

*Miniature Trimmers*

| | | |
|---|---|---|
| 3–60pF | 2 | C33,36 |

**Miscellaneous**

Relay 12V d.p.c.o. (RS 349–658); Toroids (see text); TO5 heatsink; Printed circuit boards (2); Case (see text); Phono sockets (3); ¼inch Jack socket.

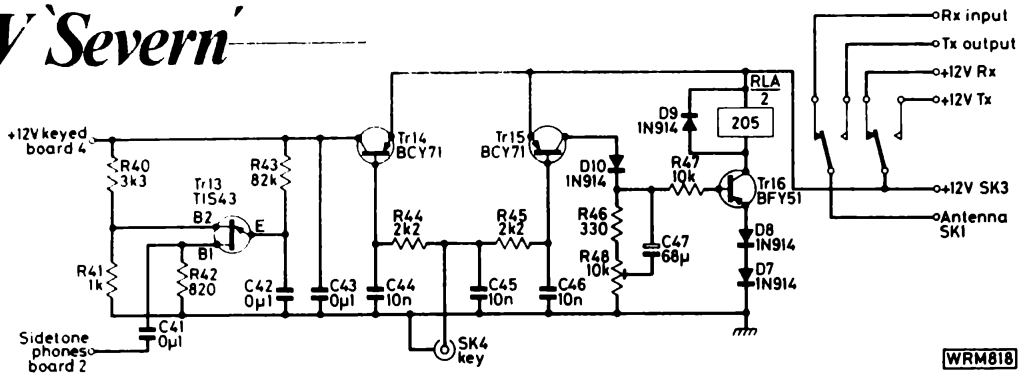



**Fig. 3.3: Circuit diagram of the change-over and sidetone generator**

## The Change-Over and Sidetone Board

The control functions for the *PW* 'Severn' are performed by the circuitry shown in Fig. 3.3. The key controls two d.c. switching transistors, Tr14 and Tr15. These are *pnp* devices and in fact any suitable silicon transistor capable of handling the current to the driver stages on the transmit board could be used. As the driver stages are keyed in the 12 volt line, Tr14 provides the required 12 volts switched on and off by the key. The 12 volt line could be keyed directly but that would result in a key "live" on both sides. Transistor Tr14 allows the more conventional approach with one side of the key connected to ground. Tr15 switches Tr16 via a time delay circuit controlled by R46/48 and C47. When the key is closed Tr15 actuates Tr16 to switch the relay RLA. On releasing the key the relay is held in for a time, governed by the decay of C47. This time can be adjusted with R48. The slight delay in RLA returning from the transmit to the receive position ensures that RLA does not clatter in and out with the keying action, but when a pause in keying occurs, it returns to the receive state. This provides "semi-break in" so that when a pause occurs in the keying, depending upon the setting of R48, the transceiver returns to the receive mode.

Resistors R44 and R45 with C44, 45 and 46 provide a degree of shaping to the keying action to round off what could be a very sharp and click prone switching action. The diodes D7 and D8 hold the emitter up from ground by around 1·4 volts as a safeguard against any leakage current in Tr16 holding in the relay when Tr16 is switched off. Diode D9 acts as a spike suppressor when the field in the relay coil collapses—remember the old induction coil at school?

The relay RLA may be any small relay capable of reliable hold-in with 12 volts d.c. and having two sets of change over contacts. The prototype used a small plug in relay bought on the surplus market with a coil resistance of 185 ohms. A suitable type is made by RS Components with a coil resistance of 205 ohms designed for p.c.b. mounting. The relay switches over the antenna from transmit to receive and switches in a 12 volt transmit and a 12 volt receive line for circuit board control.

Most c.w. operators do not enjoy "deaf keying" and like to hear their Morse as it is being sent. The simplest method is to key an audio oscillator to follow the transmitter, usually called the sidetone. The sidetone circuit is shown in Fig. 3.3 as the circuitry around Tr13. Any simple audio oscillator will serve the purpose, this one being a unijunction relaxation oscillator. What a lovely little device the unijunction is for such applications; normally used in pulse circuits, it just loves to oscillate! The circuit around Tr13 is the basic unijunction sawtooth oscillator with R43 and C42 providing the time constants which govern the frequency of oscillation. Their values were chosen to give a note of some 800Hz with a typical TIS43. This may vary with some examples of the device but the desired note can be adjusted with variation of R43 and C42. The output is developed across R42 and fed directly to the phones socket on the receiver via C41. The level can be adjusted with variation of R42. A whole range of unijunctions could be used for Tr13. The UT46 and E5557 directly replace the TIS43 but the 2N2646, 2N4891 and 2N4871 could all be used although they have different lead connections.

The p.c.b. and layout for the Control Board is shown in Fig. 3.5. In the prototype the relay was omitted from the board. This was to allow a range of relays to be used, as these are probably best bought as surplus items and may differ in mounting detail. In the prototype the relay was simply attached to the bottom of the case, close to the board, and held in place with Blu-tack. We amateurs can be a sophisticated lot. The board layout allows for C47 being a tantalum bead type and R48 an horizontal preset but doubtless a small electrolytic would fit the C47 space and a vertical type could be used for R48 with leads to mate it to the board.

The two d.c. switches, Tr14 and Tr15, are best built first and tested to see if keying does put 12 volts onto their collectors. The relay control circuitry around Tr16 can be added and tested. R48 should give a fair degree of control in the rate of fallout for RLA. The sidetone oscillator, Tr13, is then built and may be tested by connecting a pair of headphones between the output of C41 and ground. Any required adjustments of the pitch of the note can be made using R43 and C42.

## The Metalwork

As with any amateur radio project almost any type of housing can be used and the constructors' own ingenuity can come to the fore in the casework. But, if like me, you are reduced to a vice, a power drill and a few files when case making, it is easier to use a ready-made housing. The author's prototype was built in a ready-made case as shown in the photographs. This measured some 127 × 102 × 171mm and was obtained from Minffordd's of Sun Street, Ffestiniog, Gwynedd, LL41 4NE. Minffordds stock a whole range of inexpensive cabinets and cases for amateur use and will supply their cases by post. The photo in Part 1 showed the front panel layout which includes the r.i.t. control and s.w.r. meter which are discussed in the final part of this article.

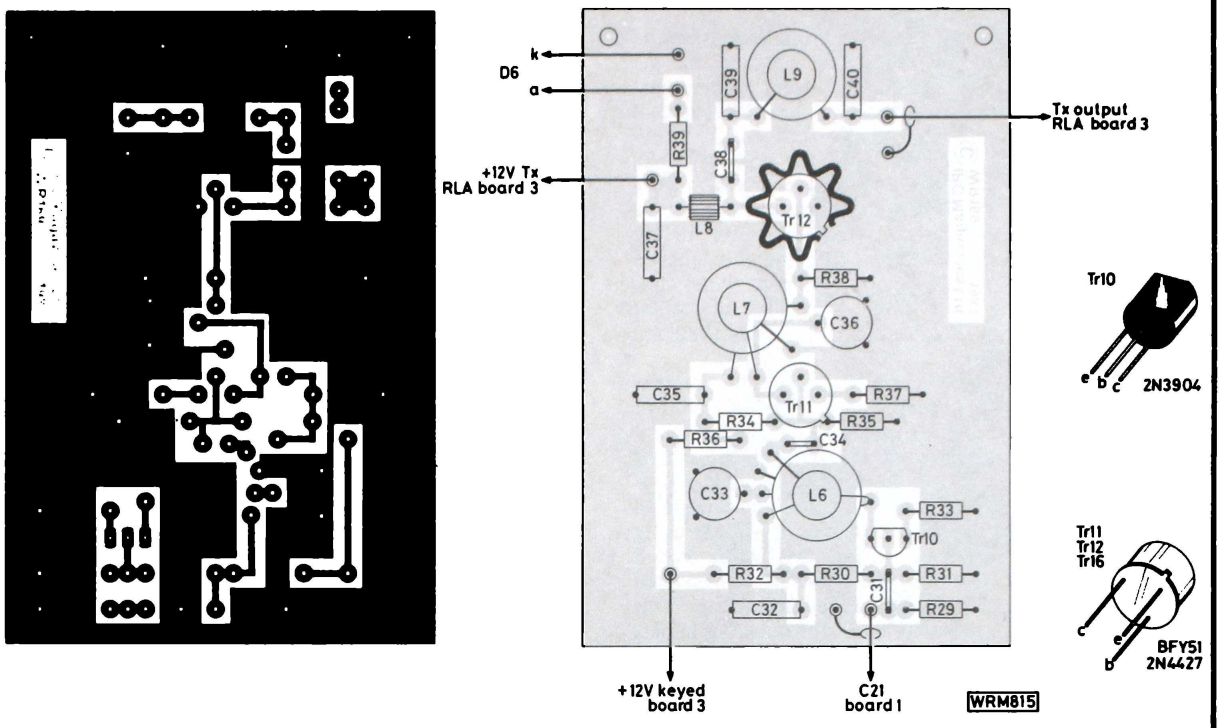
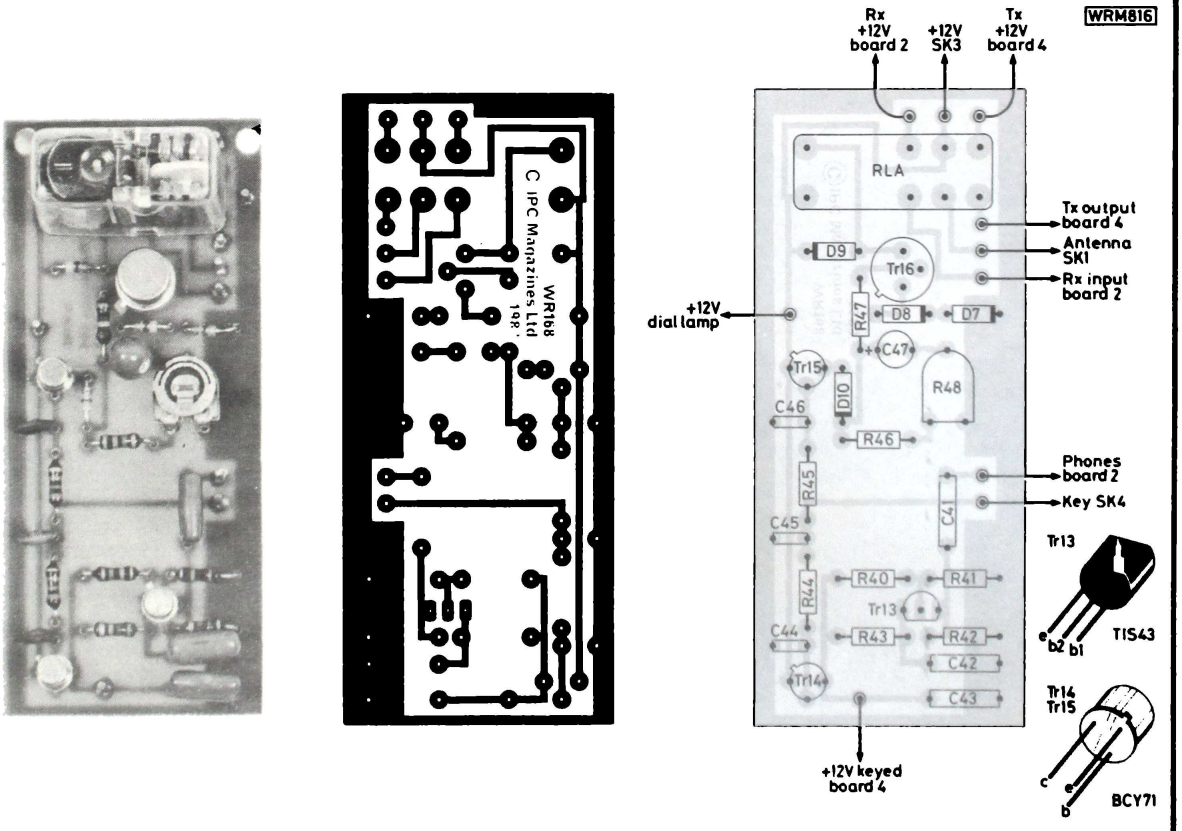


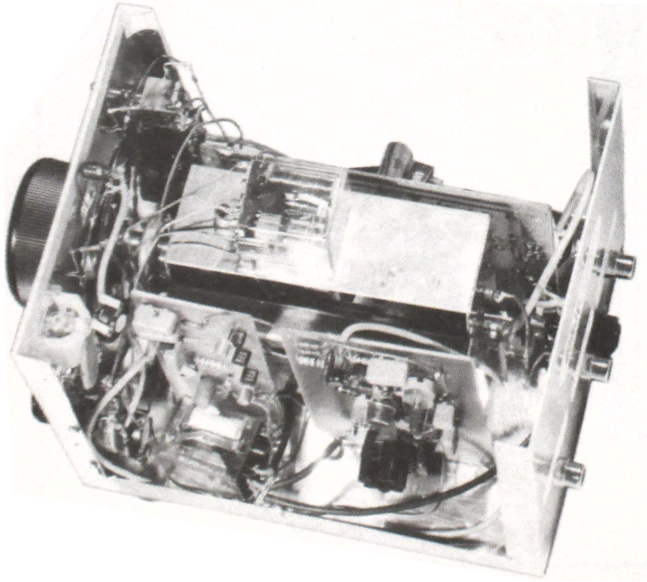

**Fig. 3.4: (Above) copper track pattern and component placement for the transmit board shown full size.**
**Fig. 3.5: (Below) the copper track pattern and component placement for the changeover and sidetone board shown full size. The photograph shows a completed sidetone and changeover board**



The back panel shows the required termination from the transceiver. A standard ¼in jack socket was used for the headphones and the other terminations were all made using the inexpensive phono sockets. These are so cheap that they have become standard in the G3RJV shack. Other connectors, especially those designed for coaxial cable, can be very expensive and phono sockets perform very well at low levels of r.f. on the short wave bands. Some may think it odd to use the same type of socket for the supply line, the key and the antenna but if they are labelled clearly, no accidents should occur. The front panel contains all the controls plus small l.e.d.s for indicating TRANSMIT and RECEIVE. These can be labelled or a red and a green type can be fitted.

Opinions vary as to the best methods for the amateur constructor to obtain an acceptable front panel finish. For the *PW* 'Severn' I used my common method of adding a false front made from tinted card. When the panel is drilled it is covered with a layer of thin tinted card, or white if you wish. A sharp marking knife will cut out all the holes required in the card. Marking is simple using Letraset rub down letters or perhaps a Rotring Pen if available. To give the final finish the whole front is covered with a layer of transparent sticky backed plastic film. This is commonly sold in stationery stores for covering books. The controls are then added. This method produces a neat front which will wipe clean and does not have the problems of coverage and chipping found with the commonly used car paint sprays.

The method of mounting the circuit boards in the case is seen in the photos. The v.f.o. is housed in a small screened box and this is mounted on its side in the centre of the case. As the tuning knob is placed in the centre of the front panel, some small standoffs will be required to raise the box to the correct height. These need to be very sturdy and four are required so that the box is rigid in use. The receiver board is mounted vertically to the left of the v.f.o. box, with the optional a.f. filter coil glued to the bottom of the case. The transmit board and control board are also mounted vertically. They are to the right of the v.f.o. box mounted longside up. Small angle brackets are required to give this vertical fixing although it is possible to solder large solder tags to the ground plane portions of the p.c.b., bend the tags 90 degrees and use these with a 6BA bolt.



The tuning rate of the v.f.o. is controlled by a small inline epicyclic drive. The method of fixing this is shown in the picture. The drive mates to the tuning capacitor shaft leaving the v.f.o. box. Such drives have one or two lugs which fix the drive rigid to the v.f.o. box. The bolts required for this will have to be quite long and are best run through standoffs for rigidity. A circular scale is added to the reduced speed collar which is the front of the main body of the drive. Any stiff material will serve the purpose: tinplate, plastic or even stiff card. Some drives have a mounting plate for a scale but if not, the scale can be Superglued to the collar. I have mounted such scales using a Terry Clip fastened to the back of the scale, which is a tight fit on the collar. Once mounted the scale can be calibrated through the little front panel window with faint pencil marks, listening for the v.f.o. on an existing receiver. The whole lot is then dismantled and the scale properly marked, perhaps with Letraset. It is worthwhile spending time on an attractive scale which can make all the difference to the finished transceiver. The window can have a Perspex cover. Notice that the prototype has different sized mounting feet on the front and back to give the tilted back effect so popular in modern equipment.

## Using the Transmitter With an Existing Receiver

Some constructors may prefer to build the transmitter alone and use it with the station receiver or the receive portion of an existing transceiver. In which case the control board need not be built. The main problem is that the v.f.o. in the *PW* 'Severn' remains on the whole time and it is not a good idea to switch it off when on receive. This will certainly result in instability. Leaving the v.f.o. on the same frequency as the receiver will result in a signal being present the whole time, so the easiest way to overcome this is to shift the frequency of the v.f.o. each time the receive state is required.

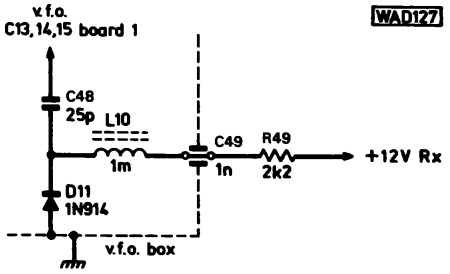



**Fig. 3.6: The small offset circuit**

A small offset circuit that will do just that is shown in Fig. 3.6. A capacitor and diode are mounted inside the v.f.o. box across the tuned circuit of the oscillator stage. When 12 volts is applied to the circuit the frequency of the v.f.o. will move out of the range of the receiver. This addition must be done with care to maintain v.f.o. stability, but rigidly mounted and decoupled with the r.f. choke and a leadthrough capacitor as shown, stability should remain. Now the transmitter can be used and when the receiver comes into operation the 12 volts applied to this circuit puts it out of the bandpass. Should the note still be heard then C48 can be increased. Arrangements will have to be made to enable the receiver to come on without the offset when the transmitter is being netted to a station.

A changeover manual switch could be used for this method of operation, but a simple electronic changeover is much better.

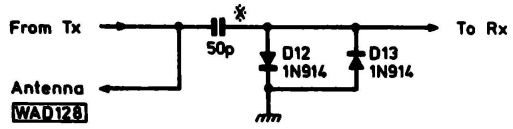
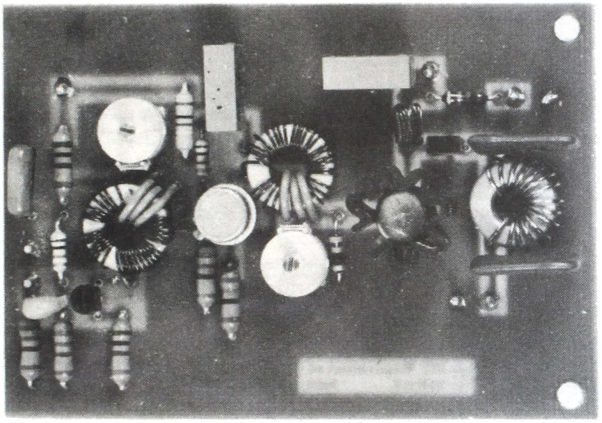
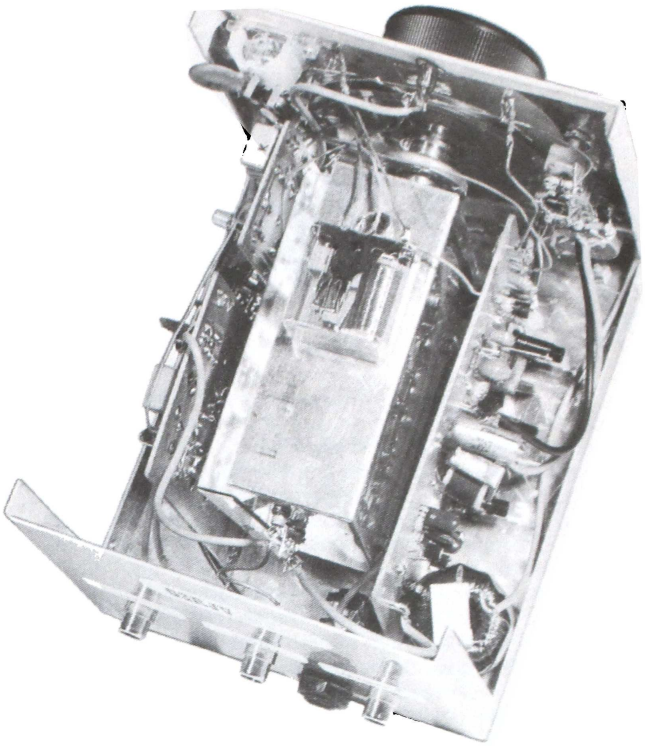
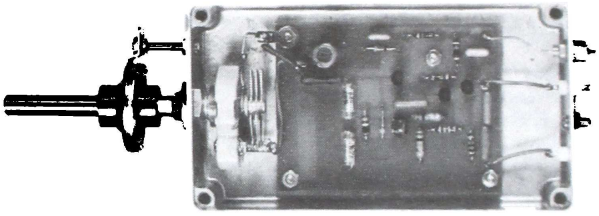



**Fig. 3.7: Electronic changeover circuit**

The circuit shown in Fig. 3.7 represents about the simplest possible electronic method of interfacing a transmitter and receiver without a mechanical switch. It originally appeared in *SPRAT, The Journal of the G QRP Club*. The transmitter and antenna are directly connected, with the receiver connected to the antenna via a small capacitor. Two diodes protect the receiver front end by limiting the amount of r.f. that can pass to the receiver. So simple yet quite effective. The capacitor may require adjustment as it needs to be a small value. Ideally it should be just high enough not to impair the sensitivity of the receiver and not so high as to cause too much r.f. leakage from the output to the receive on transmit. Obviously this does not mute the receiver and the signal will be very loud, but it is a simple matter to turn down the receiver audio gain control and use a reduced audio output to monitor the keying.







**A completed transmit board is shown above. The mechanical construction is shown at the top of the next column with a completed v.f.o. below**

| Coil | Turns | Wire s.w.g. | Former |
|---|---|---|---|
| L6 | 16+16<br>3 | 28<br>24 (pvc) | Amidon T50-2 |
| L7 | 32<br>3 | 28<br>24 (pvc) | |
| L9 | 14 | 22 | |
| L8,11 | 10 | 32 | Ferrite bead |

**Readers who intend to operate the *PW* 'Severn' should be in possession of the appropriate licence issued by the DTI to those who have passed the City and Guilds Radio Amateurs' Examination. Details may be obtained from: The Department of Trade & Industry, Radio Regulatory Department, Amateur Licensing Section, Waterloo Bridge House, Waterloo Road, London SE1 8UA.**

The *PW* 'Severn' is now complete in its basic form and a useful little transceiver it is too. The final part of this article will describe some extras for the project and say something of the techniques of low power operation with such a transceiver.

# *PW 'Severn'*

# QRP 7MHz Transceiver

PART 4

Rev. G.C. DOBBS G3RJV

Very often the home constructor in amateur radio these days is a "bits and pieces" man. He builds power supplies, station accessories and small modifications to his commercial equipment. All very satisfactory as far as it goes but the real satisfaction comes from building a complete item of station equipment like a transmitter or a receiver and telling the station at the other end of a QSO that you are homebrew. The first three parts of this series described the building of a low power (QRP) transceiver for the 7MHz amateur band to a design simple enough for the relative newcomer. By now the transceiver, or perhaps just the transmitter or the receiver portion, may have been built. This final part deals with some of the extras that go towards making the *PW* 'Severn' even more of a viable amateur radio station.

## SWR Bridge

The *PW* 'Severn' transmitter has a fixed pi-network output designed to feed into a load of 50 ohms impedance. This is common practice in amateur radio circles and true of many modern transceivers. Some antennas are bought or built to match such an output but many amateurs using "bits of wire" or multiband antennas have to put an antenna tuning unit (a.t.u.) between the transmitter and the antenna. This matches the impedance of the antenna to the characteristic impedance of the transmitter output. "You want to see 50 ohms, my boy, I'll arrange it for you!" The simplest way to ensure that the a.t.u. is correctly adjusted to present the 50 ohms required to the transmitter is to use some form of standing wave indicator. The standing wave ratio bridge (s.w.r. bridge) measures the forward and reverse current passing along the feeder line from the transmitter to the antenna via the a.t.u. Want to know more about s.w.r.? It would take more than the space here to do it justice, try one of the many amateur radio text books. It is also worth reading some of the articles which debunk the importance that s.w.r. has achieved in modern radio. It might not be everything some claim but measuring the s.w.r. is the easiest way to tune up the little *PW* 'Severn' via an a.t.u.

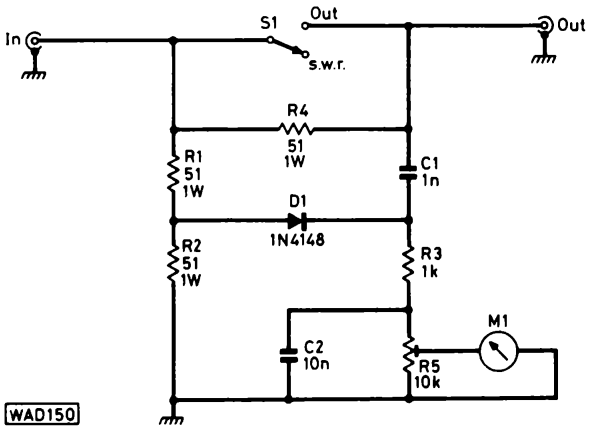



**Fig. 4.1: Simple resistive s.w.r. bridge**

About the easiest way to check the s.w.r. of a low power transmitter is to use a resistive bridge. A suitable circuit is shown in Fig. 4.1. This might more accurately be called an impedance matching bridge. Remember the Wheatstone Bridge in school physics . . . who doesn't! This circuit is based upon the same principle. R1, R2 and R4 form three arms of the bridge, the fourth being the load offered by the antenna, or antenna via the a.t.u. When all four impedances are equal there should be a null across the bridge. The reading across the bridge is indicated by the meter, M1, as a d.c. current after being rectified by D1. It is very simple to use as all that is required is to adjust the antenna or a.t.u. until M1 gives the lowest reading. Naturally, as with all such measurements, the bridge comes between the transmitter and the a.t.u.

This circuit has the obvious merit of only requiring a few cheap components and a meter. It also has the added advantage that because the bridge offers a load across the output of the transmitter, during loading up the transmitter never sees a really bad mismatch. This can be quite a saving in transistor p.a. stages which tend to die in severe mismatch conditions. The slight disadvantage is that this load offered by the bridge must be switched out during transmission or some of the precious r.f. will be dissipated in the bridge. A switch S1 cuts out the bridge in this circuit.

No special or expensive components are required. The resistors R1, R2 and R4 can be made up from two 100 ohm resistors in parallel. The meter, M1, may be one of the many surplus tape recorder meters that appear on the market at low prices. The prototype used a small square one which seemed to have a full scale deflection of around 150μA. Almost any meter under 1mA would serve as the preset, R5, controls the meter sensitivity. No layout is shown for the bridge as it is easily built "ugly style" using the leads as supports for the various components. All leads should be kept as short as possible. The bridge can easily be suspended near the output socket for the antenna on the back of the case. The meter and the switch are front panel mounted using the layout shown in Part 2 of this article. If S1 is on the front panel screened leads must be used for the wires to the switch. Some constructors may prefer to have the switch on the back panel near the socket and bridge.

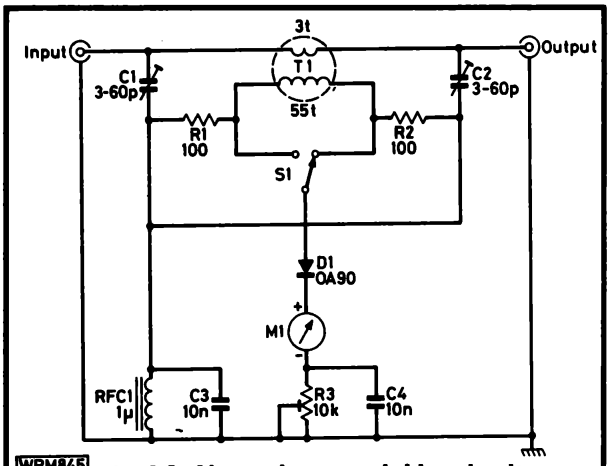
## Alternative SWR Bridge

Some constructors do not like resistive bridges because they have to be switched out when the transmitter is in use and give no indication of r.f. going to the antenna. For the "dancing needle fan" there is no real problem. Low power permits very simple versions of the classical Bruene

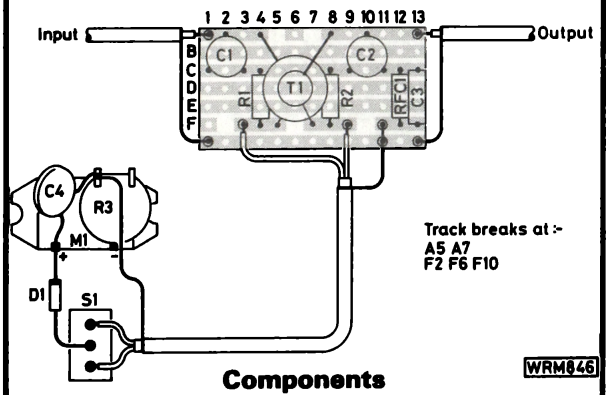


*Reprinted from Practical Wireless, August 1983*

Bridge. A suitable circuit is shown in Fig. 4.2. The signal passes through the small winding in the r.f. transformer, T1. The larger winding samples the r.f. and two signals appear at either ends of the winding at R1 and R2, 90 degrees out of phase. These signals across the resistors R1 and R2 represent the forward and reverse currents in the feeder line. Switch S1 enables either side to be selected. The signal is rectified by D1 and indicated on the meter, M1, which has a sensitivity control, R3. T1 is wound on a toroid former, the "polo mint" type cores which were used earlier in the transmitter section. The sampling winding occupies most of the circumference of the core and the signal winding is just three turns of pvc covered hookup wire around the centre of the main winding. If the circuit designations for Forward and Reverse are to apply, the two windings must be the same way round. Once again M1 is a cheap tape recorder meter. The choke, RFC1, is a 1μH r.f. choke but any similar value will do the job.




WRM845 **Fig. 4.2: Alternative s.w.r. bridge circuit**




WRM846

**Components**

| | | | | | |
|---|---|---|---|---|---|
| *Linear preset potentiometer* | | | *Moulded choke* | | |
| 10kΩ | 1 | R3 | 1μH | 1 | RFC1 |
| *Resistors ¼W 5%* | | | *Germanium diode* | | |
| 100Ω | 2 | R1,2 | OA90 | 1 | D1 |
| *Foil trimmer capacitors* | | | See text for other components | | |
| 3-60pF | 2 | C1,2 | | | |

**Winding details for T1**

55 turns 28s.w.g. enam. wire

3 turns pvc covered wire on Amidon T-68-6 toroid

**Fig. 4.3: Veroboard layout of the alternative s.w.r. meter. This layout was originally designed for 0·15inch matrix board which is becoming increasingly difficult to obtain in small pieces. 0·1inch matrix can be used but it will probably be necessary to add an extra track between tracks A and B and also to add a couple of extra holes onto the length to fit the two trimmer capacitors**

The layout in Fig. 4.3 shows the bridge built up onto Veroboard. I do not favour Veroboard for r.f. work, but this little circuit lends itself well to the method.

Twin screened lead takes the signal from the board to the switch and meter portion of the circuit. When this circuit was tried with the prototype the board was fastened with its single screw fixing to the back panel near the antenna socket and the switch, meter and associated components were on the front panel. The circuit is symmetrical and can be used either way round, in fact this is the way to set it up using C1 and C2. It can be nulled with a non-inductive dummy load of 50 ohms using C1 and C2 and then reversed and nulled again.

## Receiver Incremental Tuning

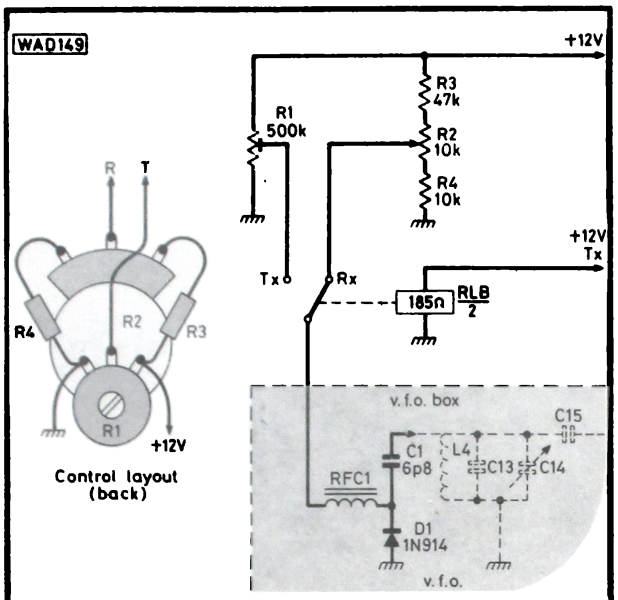
Many operators like to have some form of independent tuning of the receiver section of a transceiver which enables a small degree of offset tuning on receive without affecting the frequency of transmission. On c.w. this allows the signal to be adjusted to a comfortable listening pitch without material alteration of the transmission frequency. This is particularly useful in direct conversion transceivers, like this one, where the same v.f.o. is used for transmit and receive functions. This means, in theory, one transmits and receives on the same frequency, but ideally the receiver should be offset slightly to obtain the beatnote. It is possible to judge this to be near enough netted to the other station for practical working but receiver offset tuning is a great aid. Usually this facility is called Receiver Incremental Tuning (r.i.t.) or in some usage, especially CB, a clarifier control (ugh!).

The principle is to be able to tune the v.f.o. slightly off frequency during receive only and return to the original frequency during transmit. Fig. 4.4 shows a simple circuit that will do just that. A diode and a capacitor, C1 and D1, are placed across the v.f.o. tuned circuit. These form a varicap circuit such that small voltage changes across the diode will alter slightly the capacitance across the tuned circuit. So D1 and C1 are added to the v.f.o. circuit and taken via RFC1 to a control voltage. This voltage is controlled by R2 on receive and by R1 on transmit through the action of a relay changeover. R1 is preset so that the v.f.o. is at the same frequency when R2 is in the middle of its travel. This enables R2 to control the frequency either side of the transmitted frequency.

A word of warning at this stage—v.f.o. circuits are not to be trifled with and the r.i.t. circuitry built inside the v.f.o. box must be firm and directly wired with short leads. Some decoupling is provided by RFC1 but this is still playing about with the most sensitive part of the transceiver. RFC1 is simply a couple of small ferrite beads slipped onto the lead from D1 and C1 inside the v.f.o. box. The values given gave about a 1kHz offset either side of the transmitter frequency in the prototype, but the values of the receiver voltage divider, R2, R3 and R4, may require individual adjustment with other examples of the *PW* 'Severn'.

The relay is a small 12 volt changeover relay of any type and ought to be mounted on top of the v.f.o. box close to the point where the lead is led through the box. I stuck mine on with Blutack. This should be as close as possible to the tuned circuit. The relay is energised by the 12 volt transmit line. R1, R2, R3 and R4 are all mounted around the front panel placing for R2, the r.i.t. control. Short, direct leads should take the transmit and receive voltage to the relay. The metal case of R2 ought to be earthed and short wiring used throughout. A layout for the back of the r.i.t. control is shown.

The best way to set up the r.i.t. is to listen to the v.f.o. signal on another receiver and adjust R1 until it is at the




**Components**

See text for components.

**Fig. 4.4: The r.i.t. circuit diagram for the *PW* 'Severn'**

same frequency as R2 when R2 is set towards the centre of its travel. Ideally the operator should know where to set R2 to listen at comfortable pitch to a signal on the same frequency as the transmitted signal. This can be done with another signal used in conjunction with the v.f.o. and second receiver. This signal could be from a crystal oscillator or a signal generator. This signal is zero beated with the v.f.o. signal on the spare receiver and then R2 is adjusted until that signal can be heard at a comfortable listening pitch. This may require a little trial and error with R1 and R2 to get the setting on R2 in about the centre of the control travel. A mark can be made on the front panel to give the setting that enables the receiver portion to give a signal which is comfortable listening and gives a transmission that is zero beat. Remember that it is usual to tune from the low frequency end of the band when working on the 7MHz band. It is fiddly but worth it in terms of being assured that the *PW* 'Severn' transmits on the same frequency as the station to be called. The r.i.t. control must be returned to the marker at the beginning of every new QSO.

## Power Supply

The *PW* 'Severn' works from a 12 volt supply and storage batteries of reasonable size will provide suitable power. However, most people prefer, at least for home station working, to use a mains supply. Although the v.f.o. has a built-in stabilised line it is important to use the *PW* 'Severn' on a stable supply. Many amateurs have such supplies as a standard part of their station setup but in case this is lacking the circuit in Fig. 4.5 shows a suitable supply. The circuit uses one of the three pin regulator integrated circuits which can handle just over one amp. They are quite inexpensive and this current rating is more than adequate for our QRP transceiver.

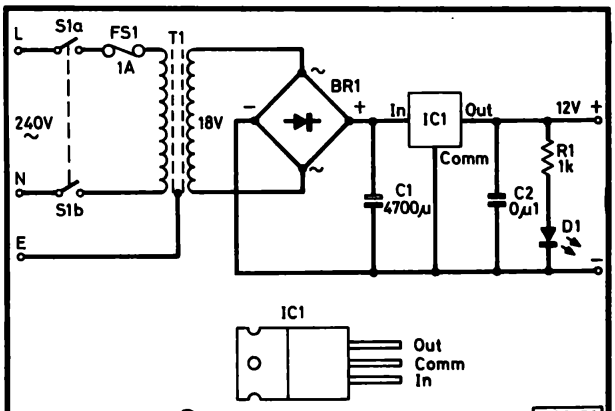
The circuit explains itself and can be built in almost any type of housing. A good degree of smoothing is essential for this transceiver as all direct conversion transceivers are very prone to hum pickup from supply lines. They can be a good test for a 12 volt bench supply. IC1 ought to have a small heatsink and C2 should be mounted as close to the output pin as possible. R1 and the l.e.d. indicate that the supply is on.

The supply should present no problems even to the beginner in construction. Although a bench supply is useful, don't overlook the use of batteries. A small motorcycle 12 volt lead-acid battery or the Dryfit lead-acid batteries would be very suitable for the low current demands of the *PW* 'Severn'. This also enables the transceiver to be used as a portable unit or as a second station in another part of the house.

## What About Antennas?

It is a widely held belief that successful low power operators must use mighty antennas but this is far from the case. Most QRP operators are either keen on home construction and money saving or shun the advent of the expensive commercial aspects of the hobby. This philosophy usually results in QRP operators being users of simple wire antennas, often in confined spaces. Many types of antenna could be used with the *PW* 'Severn'. A simple dipole would work very well or a multiband system like the G5RV antenna or just a bit of wire with an a.t.u. Fig. 4.6 gives just one suggestion for a simple antenna that has been used with good results by QRP operators. It is the oft forgotten W3EDP system. This entails feeding a 25·6m wire against short counterpoises for each band. For the 7MHz band the counterpoise is only 5·2m long and can be trailed around the floor of the shack or outside the window.

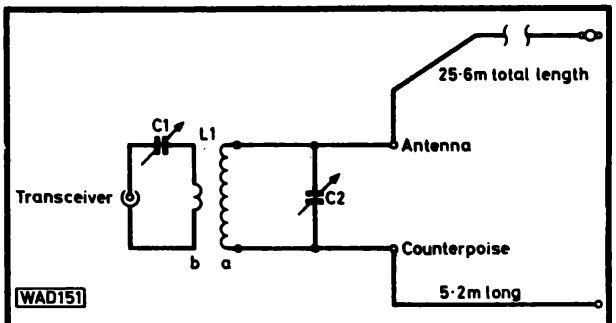
Nearly 26 metres! Can I get that in my little garden? The advantage of this antenna is that the radiating wire does not mind being bent, in fact it can be an asset in giving a wider radiation pattern. I have used this antenna with the main wire bent around several times to fit into a small space. In fact the first time I used it was on 7MHz with a little 1 watt transceiver like the *PW* 'Severn' and my first contact was with ZB2OE. The W3EDP requires a simple




**Components**

| | | |
|---|---|---|
| *Mains transformer* | | |
| 9+9V 20VA | 1 | T1 |
| *Bridge rectifier* | | |
| 50V, 1A | 1 | BR1 |
| *Integrated circuits* | | |
| 7812 | 1 | IC1 |

**Fig. 4.5: A suitable and simple regulated power supply for use with the *PW* 'Severn'**




**Winding details**

L1a 10 turns 24s.w.g. pvc covered wire on 25mm dia. former
L1b 2 turns 24 s.w.g. pvc covered wire over centre of L1a
See text for details of C1,2

**Fig. 4.6: Simple a.t.u. for use with the *PW* 'Severn' transceiver and the W3EDP antenna**

a.t.u. of the type that is normally used for an open wire feeder antenna. It is useful in that it can be used from upstairs rooms without problems, being a balanced system.

The a.t.u. is simple and can be built quite small using junk components. Remember this is QRP so a lot of the a.t.u. building problems just disappear. L1 is a conventional coil wound onto any 25mm diameter former. C1 and C2 are both polycon variable capacitors of the type used in cheap transistor a.m. radios for the main tuning control. These are usually two gang controls of some 200pF per section. One section only is used for C2 and both sections are paralleled for C1. Cheap polycons for an a.t.u.? Well, at these power levels they seem to perform adequately and can cost nothing if culled from scrapped oriental a.m. radios. Look for the ones with longer shafts so that a control knob can be used.

The a.t.u. is very simple to use. C2 is tuned to get the best dip on reversed current on an s.w.r. bridge and C1 is adjusted for optimum output with lowest s.w.r. The method of setting up soon becomes clear in use. Try a W3EDP—you might like it and it can cost nothing.

## Using the *PW* 'Severn'

QRP operation is a viable proposition on today's amateur bands as many radio amateurs prove daily the world over. It calls for all the skill and cunning which every good operator should use to gain QSOs. Remember that the signal will probably be some 3 "S" points down on the average station. Calling CQ is wasteful on time, except perhaps from time to time on the International QRP Calling Frequency of 7030kHz. Look for stations who are calling CQ and call them. Check which stations are working stations known to be relatively close, what reports are they getting? Who is working who? Listen around for a while before beginning to transmit. In fact, do all the things any good operator would do.

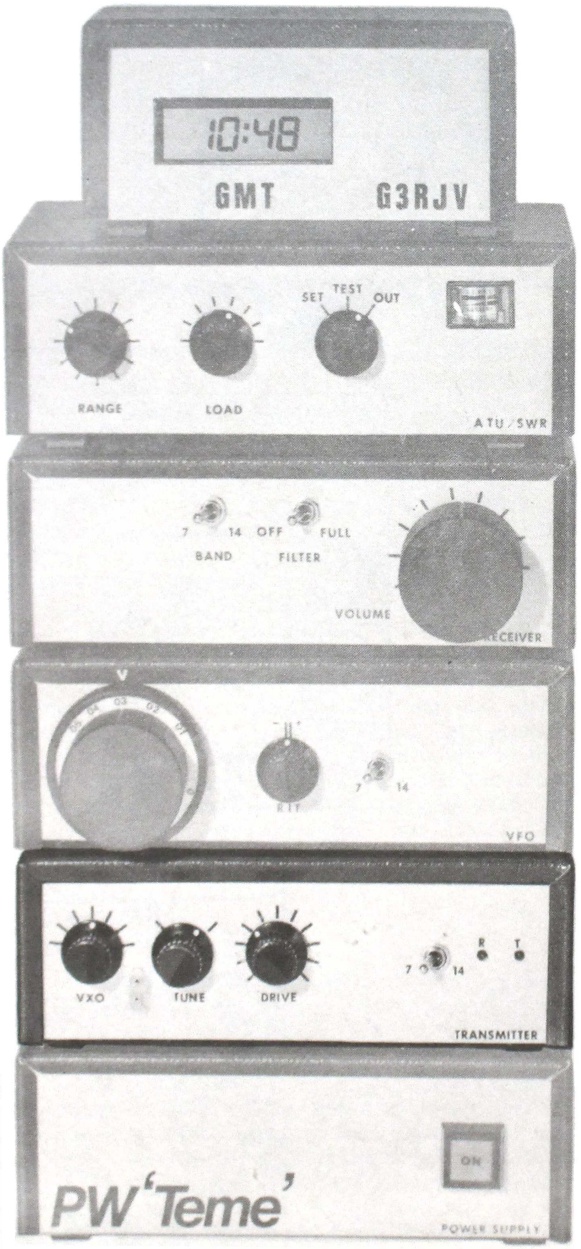
Tail ending is another good way to make QSOs. Wait until a QSO is finished. Allow time for that little extra exchange of dits or 73 at the end, and call the station from the two that you wish to work. It is great fun, other operators will be pleased to work a homebuilt low powered station. Another useful tip is to avoid saying you are QRP until after the other station has given his report . . . it makes a surprising difference! Be bold, enjoy yourself. The satisfaction of QSOs using low powered homemade equipment has to be experienced. ●

IT WAS BUILT BY SEPPUKU HARAKIRI IN 1961. NOWADAYS THE WHOLE SYSTEM WOULD
Benny
BE MINIATURIZED AND PUT ON ONE SINGLE CHIP, BENNY-SAN!
THAT'S INTERESTING! BUT I JUST WONDER- HOW DO YOU MINIA- -TURIZE ...
-THE OPERATOR!
KAMIKAZE IS WORKING ON IT!

THIS MONTH-TRANSMITTER

# PW 'TEME' Modular QRP Transceiver

Part 1 by Rev. George Dobbs G3RJV




In the twenty or so years that I have held an amateur radio licence the ethos of the hobby has changed completely. I actually recall when radio amateurs boasted about how cheap their station was and now, so often, the reverse is true. Recently I was answering questions from a group of RAE Candidates and found that they really only had two questions to ask, "What should I buy?" and "How much is it going to cost me?" Yet in spite of the current trends in the hobby it is possible to participate fully and have a lot of enjoyment from the use of relatively simple low-power, home-made equipment. Hundreds of pounds and hundreds of watts are not required on the h.f. bands. As William of Occam (1290-1350) said,

> "It is vain to do with more,
> what can be done with less."

This series of articles will describe a progressive h.f. c.w. amateur radio station for the popular 7 and 14MHz bands which can be built by the average constructor at low cost using easily obtainable components. The project takes the form of a series of add-on modules. It begins with a basic transmitter, which can be used in its own right, then further modules are added to build up to a reasonably sophisticated and highly usable amateur radio station. So right from the beginning, with the construction of the first module, the constructor has something which can be used. It is then up to the individual to add modules according to taste, ability or pocket. Each module is housed in an identical smart case. The cases are stackable, as the station grows, and smart enough to grace any room in even the most fastidious home.

## The Modules

The make-up of the final station when all the modules are completed is shown in Fig. 1.1. The basic unit is a transmitter for the 7 and 14MHz bands (with a 10·1MHz option, if required). The transmitter module also contains the changeover (transmit/receive) control circuitry which produces a number of switched power lines for controlling sections of the other modules. These lines are distributed to the various modules via a standard 5-pin DIN plug and socket on each box. The transmitter is low powered (QRP) having a drive control which can give an r.f. output from nothing to 3 watts. That might seem very low but some avid QRP operators would regard 3 watts output as being too much for them!

The basic transmitter is a variable crystal oscillator (VXO) circuit which only allows limited frequency coverage, so the second module provides a variable fre-



*Reprinted from Practical Wireless, November 1984*

quency oscillator (v.f.o.) to enable the c.w. portion of the bands to be covered. The v.f.o. is on 7MHz, and a doubler on the same board allows for a 14MHz output. These two modules together give a very useful transmitter for two amateur bands and, used in conjunction with an existing receiver, could make up a viable station. This would provide a lot of satisfaction from making contacts with a home-made transmitter. But why stop there? Confound the opposition by adding the receiver module and operate a completely home-made station. The existing v.f.o. and doubler are used, together with a direct conversion receiver board to provide full transceiver facilities. The common selectivity problems usually associated with direct conversion receivers are minimised by good front end tuning and a built-in, two-position audio filter.

The station may be completed by adding a stabilised 12 volt power supply unit to save the inconvenience of battery supplies. The supply is made compact by using a toroidal mains transformer. It is well smoothed to overcome the hum problems sometimes apparent when using a direct conversion receiver on a mains operated power supply. The final module contains a standing wave ratio (s.w.r.) meter for tuning up the transmitter and an antenna tuning unit (a.t.u.) to enable a wide range of antennas to be used with the transceiver. The a.t.u. assumes the use of an end-fed piece of wire as an antenna but alternative circuits (that will fit the case) are discussed for other configurations.

The whole project is easy to build, costs very little—in fact the cost is spread out because of the modular approach. NO SPECIALISED TEST EQUIPMENT IS REQUIRED to build any of the modules. The constructor only requires a reasonable bench multimeter, in the 20 000 ohms per volt class, an existing amateur bands receiver to identify the signals in the early stages of construction, and a simple diode probe, which is built as part of the project. If a newcomer is thinking of buying a multimeter for this project, all that is required is a medium priced analogue meter (one with a needle scale) rather than a digital meter. As with a lot of amateur construction work, we will be using the meter to measure changes and peaks, rather than exact finite readings, and such changes are better seen in the swing of a needle.

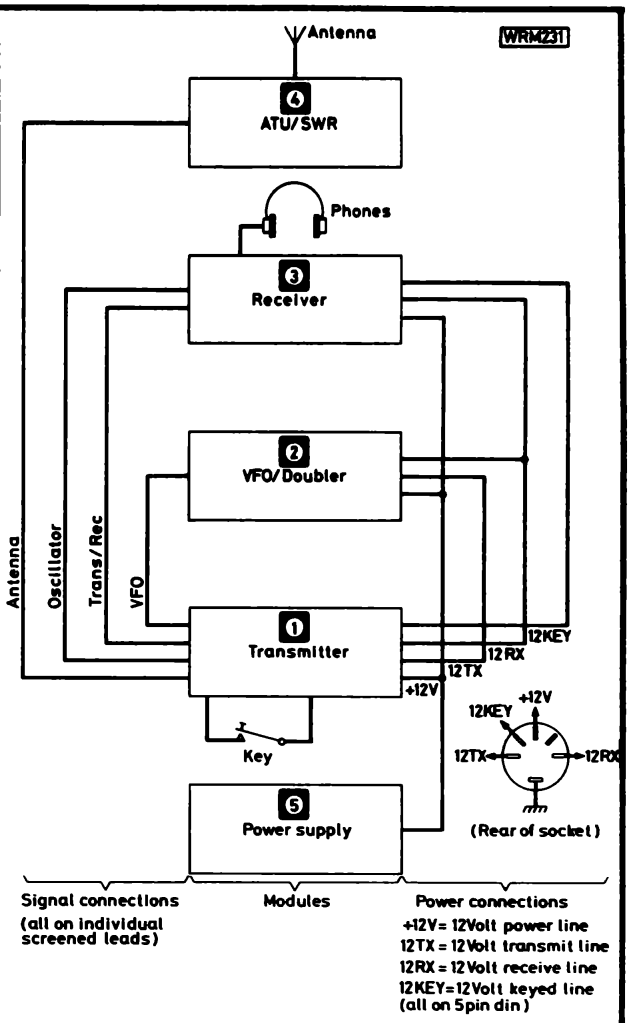



**Fig. 1.1: The PW "Teme" modular transceiver system interconnection arrangements**

To avoid confusion between the several modules making up the PW "Teme" project, each has been numbered as follows:

| | |
|---|---|
| Transmitter | Module 1 |
| VFO/Doubler | Module 2 |
| Receiver | Module 3 |
| ATU and SWR Bridge | Module 4 |
| Power Supply | Module 5 |
| Digital Clock | Module 6 |

Each drawing and components list will state which module number it refers to. In the text, component references will be prefixed by the module number. For example, resistor R9 in the Transmitter Module would be called 1R9, while R9 in the Receiver Module would be 3R9.

## The Transmitter Circuit (Module 1)

The circuit for the transmit module is shown in Fig. 1.2. The amateur radio literature is full of circuits for, and myths about, little crystal-controlled transmitters. Many are much simpler than this circuit but practice shows that over-simplified transmitter circuits can be prone to all manner of problems. The power amplification section (1Tr2 and 1Tr3) comes from a conversation I had with Wes Hayward W7ZOI, the doyen of QRP circuit design, when we met in Houston at the ARRL Convention in 1983. This broadband amplifier circuit uses negative feedback in both stages, is very stable and easily reproducible without problems. The DRIVE control, 1R5 allows for a power range of zero to 3 watts of r.f. output using the sturdy BLY33 transistor in 1Tr3.

The oscillator stage, 1Tr1, is a simple crystal oscillator using a fundamental frequency crystal, for the 7 or 14MHz bands, as a feedback element. The series variable capacitor 1C2 allows some frequency shift in the oscillator. The amount of frequency offset available from 1C2 will vary according to the band and specific crystals. A tuned circuit, 1L1 and 1C3, tunes out the 7 or 14MHz signal according to the band in use and link winding 1L2 feeds the DRIVE control, 1R5, a 1kΩ linear carbon potentiometer.

The driver stage, 1Tr2, is coupled via a wideband matching transformer, 1L3, into the power amplifier (p.a.) stage, 1Tr3, which requires a heatsink of the "star type" designed for a TO-5 transistor case. The collector load, 1L4, is a small r.f. choke wound from a few turns on a small ferrite bead. Capacitor 1C10 then couples the output

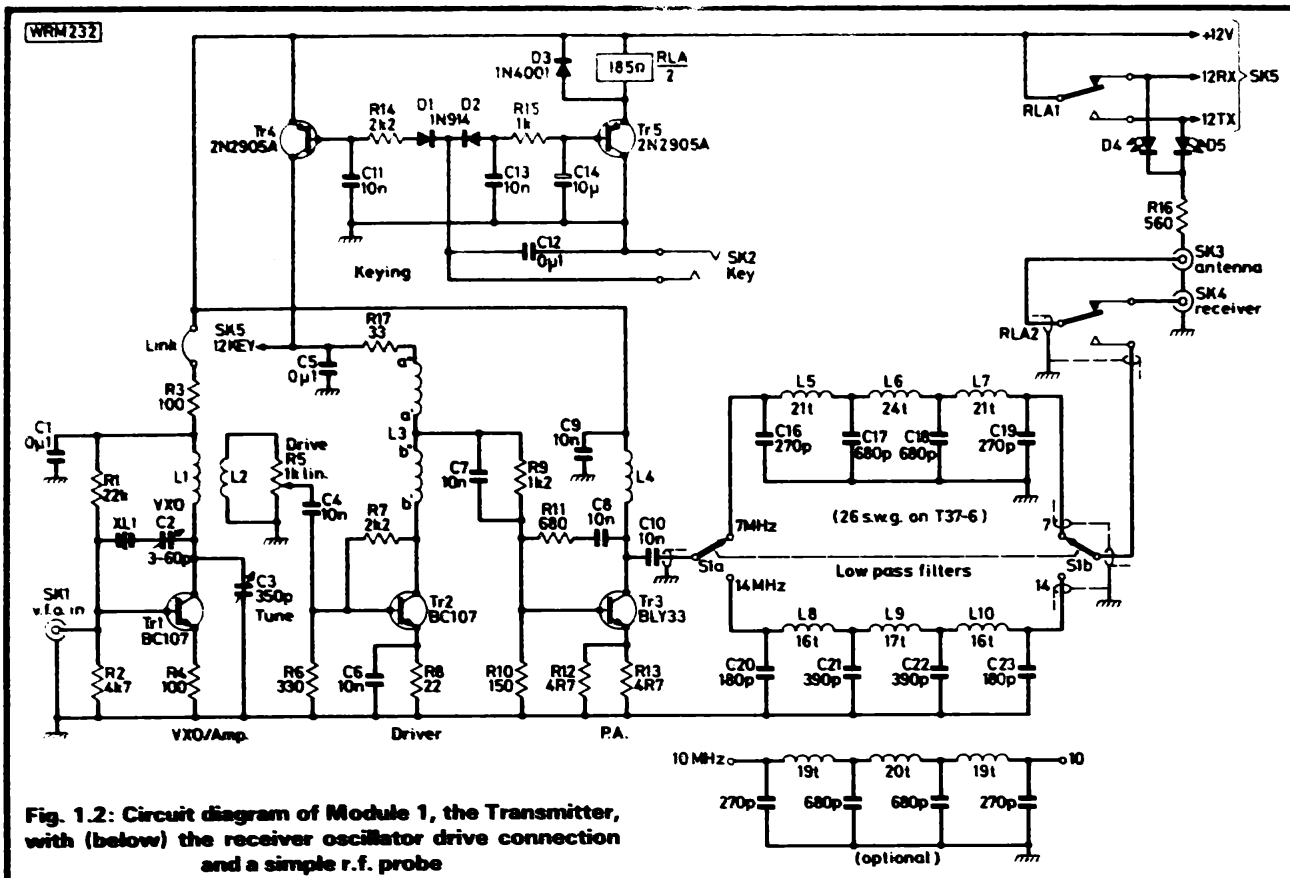
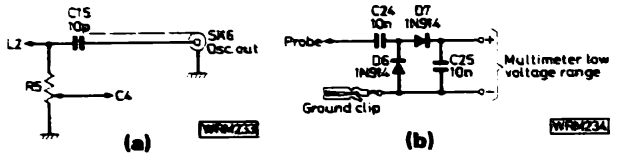



**Fig. 1.2: Circuit diagram of Module 1, the Transmitter, with (below) the receiver oscillator drive connection and a simple r.f. probe**




into switchable low-pass filters. A double-pole change-over switch, 1S1 selects either the 7 or 14MHz filter.

The low-pass filters are seven-segment, standard value capacitor filters of the type popularised by Ed Wetherhold W3NQN. Simpler methods can be used to tune the output of a QRP transmitter but harmonic suppression is important even in low power transmitters. These filters, based upon the computer standardised values of W3NQN, are compact, inexpensive and provide high harmonic rejection with little attenuation of the output. The values required are listed in the chart of Fig. 1.4. The correct toroid cores and good quality silvered mica or polystyrene capacitors must be used for these filters.

Two d.c. switching transistors, 1Tr4 and 1Tr5, provide the keying and change-over control circuits for the module. Note that 1Tr4 and 1Tr5 are *pnp* transistors. The key operates both 1Tr4 and 1Tr5 through 1D1 or 1D2. When the key is down, +12 volts is switched onto the collector of 1Tr4 which keys the transmitter through the driver stage 1Tr2. A little shaping to improve the keying characteristics is provided by 1C12, 1R14 and 1C11. Also when the key is down 1Tr5 conducts and energises the d.p.c.o. relay 1RLA/2. The electrolytic capacitor 1C14 holds the contacts of 1RLA in the energised position for a small interval of time. The changover from transmit to receive is controlled by 1RLA, a form of semi-automatic break-in is the result.

When keying begins the circuits switch to the transmit condition and will not release from this condition until the key has been released. The delay caused by 1C14 allows the transmit condition to prevail during normal keying speeds so that the relay does not clatter in and out with every action of the key. The delay speed can be adjusted by changing the value of 1C14. The relay changes the antenna over from the receiver to the transmitter. It also switches a 12 volt line to provide a 12 volt receive (12 RX) or a 12 volt transmit (12 TX) control voltage. These lines are used in later modules as is the 12 volt keyed (12 KEY) line taken from the collector of 1Tr4. The 12 TX and 12 RX lines are also used to switch two small l.e.d.s, 1D4 and 1D5, which give a front panel indication of the status of the transmit module.

## Construction

The transmit module is built on one printed circuit board. The layout is shown in Fig. 1.3. The transmit board is best built a section at a time beginning with the oscillator stage, 1Tr1, so that each stage can be tested in turn. The only test equipment required is a multimeter with a simple r.f. probe and perhaps a station receiver. The circuit for the r.f. probe is shown in Fig. 1.2(b). This probe is used in conjunction with a multimeter. The probe tip is placed upon a part of the circuit and the ground clip is connected to the ground end of the circuit or the transmitter case. The r.f. signal is converted into a d.c. voltage by 1D6 and 1D7. This represents a peak-to-peak reading of the r.f. voltage present at the probe and can be used for checking the presence and progress of the r.f. signal. The prototype r.f. probe was made on an offcut of printed circuit board material, the simple track pattern being cut with a lino cutter blade. A small piece of Veroboard could be used instead. The leads to the multimeter must be screened to

## ★ components

### MODULE 1 TRANSMITTER

**Resistors**

*¼W 5% carbon film*

| | | |
|---|---|---|
| 4·7Ω | 2 | R12,13 |
| 22Ω | 1 | R8 |
| 33Ω | 1 | R17 |
| 100Ω | 2 | R3,4 |
| 150Ω | 1 | R10 |
| 330Ω | 1 | R6 |
| 560Ω | 1 | R16 |
| 680Ω | 1 | R11 |
| 1kΩ | 1 | R15 |
| 1·2kΩ | 1 | R9 |
| 2·2kΩ | 2 | R7,14 |
| 4·7kΩ | 1 | R2 |
| 22kΩ | 1 | R1 |

*Potentiometer, carbon track*

| | | |
|---|---|---|
| 1kΩ (lin) | 1 | R5 |

**Semiconductors**

*Transistors*

| | | |
|---|---|---|
| BC107 | 2 | Tr1,2 |
| BLY33 | 1 | Tr3 |
| 2N2905A | 2 | Tr4,5 |

*Diodes*

| | | |
|---|---|---|
| 1N914 | 4 | D1,2,6,7 |
| 1N4001 | 1 | D3 |
| 3mm l.e.d.s | 2 | D4,5 |

**Inductors**

L1–10 See text and Fig. 1.4

**Capacitors**

*Miniature ceramic plate*

| | | |
|---|---|---|
| 10pF | 1 | C15 |
| 10nF | 10 | C4,6–11,13,24,25 |
| 0·1µF | 3 | C1,5,12 |

*Polystyrene or silvered mica*

| | | |
|---|---|---|
| 180pF | 2 | C20,23 |
| 270pF | 2 | C16,19 |
| 390pF | 2 | C21,22 |
| 680pF | 2 | C17,18 |

*Electrolytic, 16V double-ended*

| | | |
|---|---|---|
| 10µF | 1 | C14 |

*Variable*

| | | |
|---|---|---|
| 350pF (see text) | 1 | C3 |
| 60pF (see text) | 1 | C2 |

**Miscellaneous**

Phono sockets (4); 2-pole ¼in jack; 5-pin DIN socket; Crystal holder, HC25U; Relay d.p.c.o., 12V 185Ω coil, "Continental" type (Maplin FX27E or similar); Switch d.p.c.o. min. toggle; Heatsink, push-fit TO–5 for Tr3; Printed circuit board; Case, see text and Buying Guide; Feet, knobs (3), etc.

## BUYING GUIDE

**Crystals:** Amateur Band crystals for the transmitter may be obtained from P. R. Golledge Electronics, Merriott, Somerset for 7030 and 14 060kHz (QRP Calling Frequencies) and 14 030, 14 040 and 14 050kHz. These are HC25U crystals priced at £4.00 each (£3.50 each for a G-QRP Club Member) including VAT and postage.

**Toroid Cores:** All the toroid cores for the transmitter can be obtained from SMC(TMP) Unit 27, Pinfold Workshops, Pinfold Lane, Buckley, Clwyd CH7 3PL, (0244) 549563, or from Cirkit. Please note, with the exception of L3, the toroids are **iron powder,** not ferrite cores. Most unmarked surplus toroid cores are ferrite.

**Cases:** The J6 Instrument Case is available from Minffordd Engineering, Sun Street, Ffestiniog, Gwynedd LL41 4NE. (076676) 2572.

**P. A. Transistors:** The BLY33 is available from BCD Electronic Services, 200 Hessle Road, Hull, (0482) 225437, or Heller Electronics Ltd., 49 Blossom Waye, Hounslow, Middlesex TW5 9HB. Other similar transistors could be substituted.

**Front Panel Legends:** Water slide transfers (in white only) of amateur radio legends are available from John Kaine, 74 Campden Mews, London N1 9BX for £1.25 a sheet, inc postage.

**Approximate Cost** £23

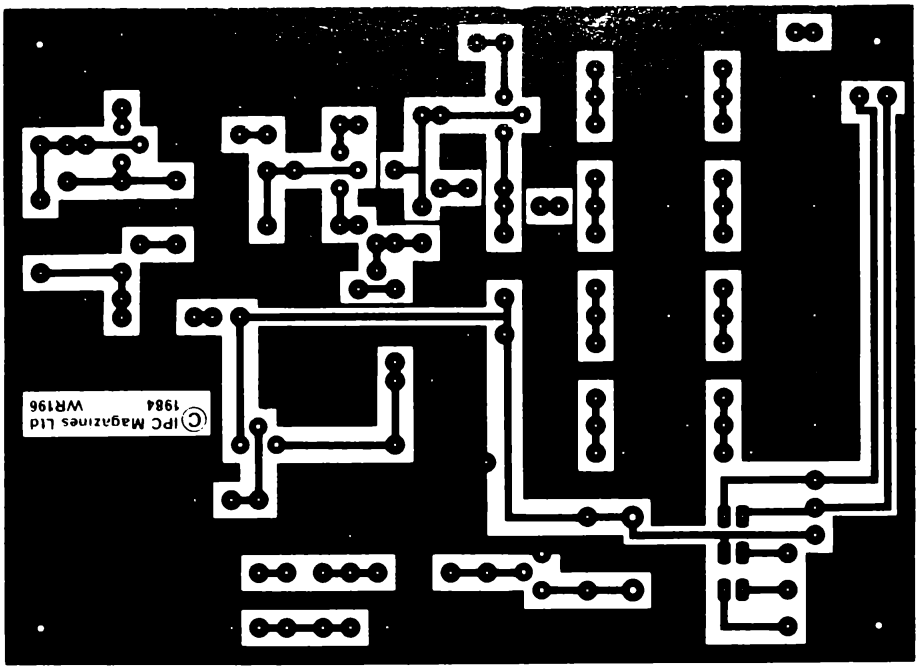
**Construction Rating** INTERMEDIATE

prevent stray r.f. pick-up. All the measurements for the prototype were made with this probe and an inexpensive 20 000 ohm per volt multimeter.

The variable capacitor required for the oscillator frequency shift control VXO has a value of some 3-60pF and that used in the prototype was made from a semi-airspaced trimmer, being a much cheaper alternative than an airspaced variable capacitor. *(Note: Some of these semi-airspaced trimmers tend to have a very short life if moved frequently—Editor).* The trimmer is mounted onto an offcut of Veroboard and a short piece of 6mm (¼in) diameter shafting (in the prototype, excess from the potentiometer 1R5) is counter-bored and glued onto the screwdriver control of the trimmer. This is shown in Fig. 1.5. The crystal, 1XL1 is held in an HC25U crystal holder on the front panel. Coils 1L1 and 1L2 are wound onto a single T37-6 toroid core as shown in Fig. 1.4. The main winding, 1L1 should occupy some 80 per cent of the core, each time the wire passes through the centre of the core counts as one turn.

The output tuning capacitor for 1Tr1, 1C3, covers the 7 and 14MHz bands with 1L1. This variable capacitor is a polycon semi-airspaced type of the sort used in cheap Far Eastern a.m. radios. This could be culled from such a radio but ensure there is enough control shaft to take a knob. A suitable variable capacitor can be bought from Cirkit (type CY2-3217Z). Usually such capacitors have two sections of some 350pF and may have smaller sections for f.m. tuning. Using an ohmmeter, identify the connection which is common with the shaft and join that tag to ground. Inspect the capacitor to identify a tag that goes to the fixed vanes of a large tuning section and connect that tag to 1L1.

Build the first stage as far as 1R5 and test that the oscillator works. Set the r.f. probe up with a multimeter on a low voltage scale (say 10 volts). Insert a 7MHz band fundamental crystal in the crystal socket and apply 12 volts to the top of 1R3. Attach the probe to the top end of 1R5 and adjust 1C3 until the voltmeter indicates a peak reading, which will probably be in the order of 3·5 volts. The signal can also be located on a receiver capable of tuning the frequency of the crystal. The same test can be tried with a 14MHz band fundamental crystal. Again it should be possible to obtain an output peak using 1C3.




Readers who intend to operate the *PW* Teme should be in possession of the appropriate licence issued by the Department of Trade and Industry to those who have passed the City and Guilds Radio Amateurs' Examination. Details may be obtained from: The Department of Trade & Industry, Radio Regulatory Department, Amateur Licensing Section, Waterloo Bridge House, Waterloo Road, London SE1 8UA.

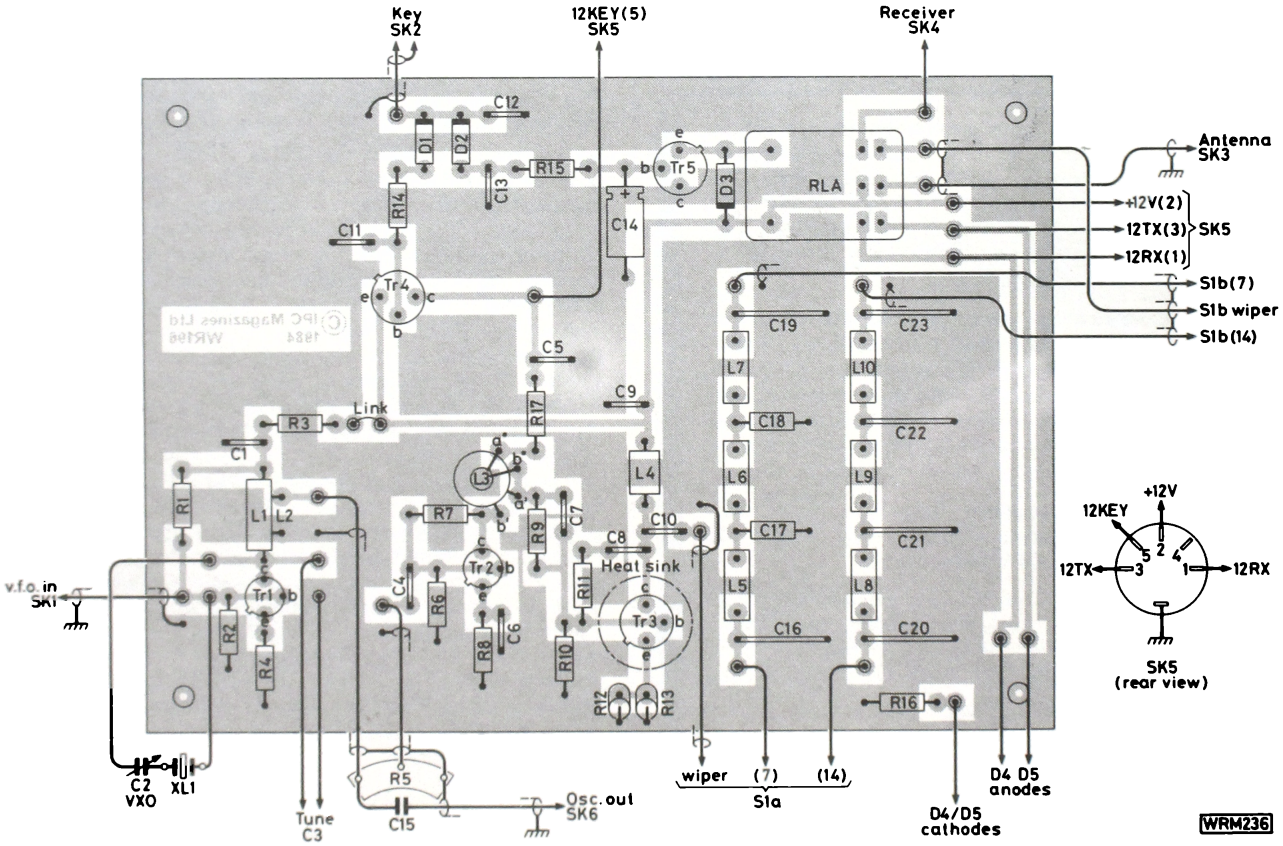
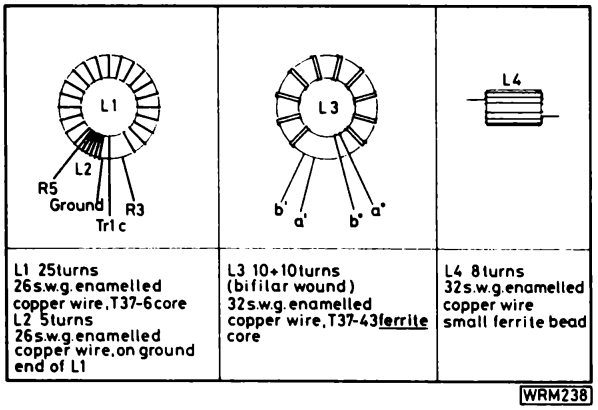



**Fig. 1.3: Full-size printed circuit track pattern and component layout and wiring diagram for Module 1, the Transmitter**

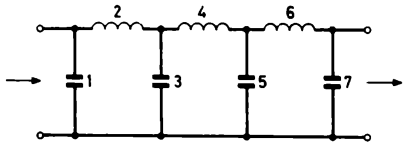
The driver stage may now be constructed as far as 1R10. The transformer 1L3 is wound on a ferrite core with a bifilar winding. The T37-43 core is ideal but almost any surplus small ferrite core would serve in this position. A bifilar coil is wound by making two windings side by side over the small core. Take enough wire to wind two windings of 10 turns around the core. Place the wires side by side and twist them together, making roughly 8 twists per inch. The 10 turns are then wound onto the core. The start and finish of both windings must be identified using the ohms range on a multimeter and connected as shown in Fig. 1.2. With the oscillator working and peaked for




| L1 25turns 26s.w.g.enamelled copper wire, T37-6core L2 5turns 26s.w.g.enamelled copper wire, on ground end of L1 | L3 10+10turns (bifilar wound) 32s.w.g.enamelled copper wire, T37-43ferrite core | L4 8turns 32s.w.g.enamelled copper wire small ferrite bead |
|---|---|---|

WRM238

7-ELEMENT LOW-PASS FILTER COMPONENTS




WRM239

| ELEMENT / BAND | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| 7MHz | 270 pF C16 | 21 turns L5 | 680 pF C17 | 24 turns L6 | 680 pF C18 | 21 turns L7 | 270 pF C19 |
| 14MHz | 180 pF C20 | 16 turns L8 | 390 pF C21 | 17 turns L9 | 390 pF C22 | 16 turns L10 | 180 pF C23 |
| Optional 10·1MHz | 270 pF | 19 turns | 560 pF | 20 turns | 560 pF | 19 turns | 270 pF |
| INDUCTORS: 26 s.w.g. enamelled wire on T37–6 toroid cores<br>CAPACITORS: Silvered mica or polystyrene types | | | | | | | |

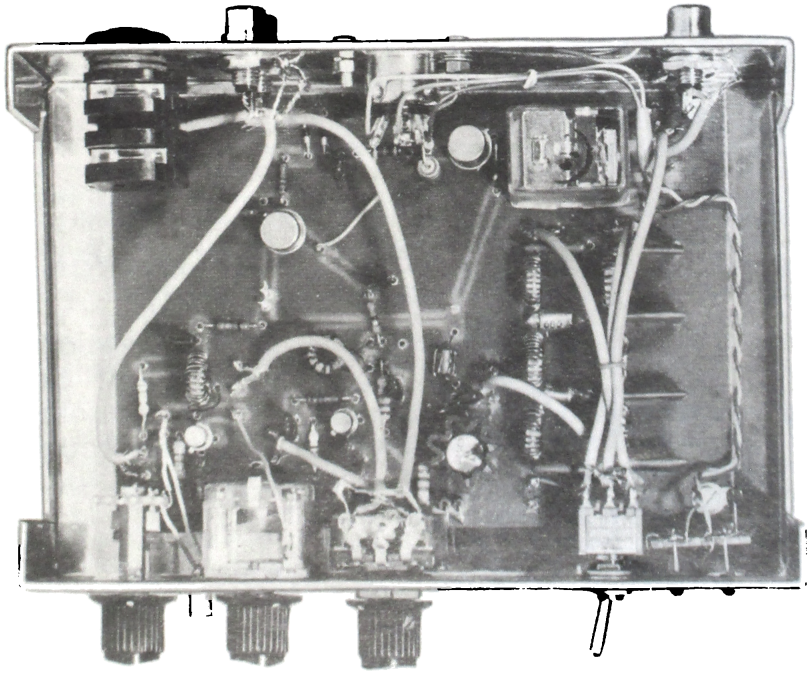
**Fig. 1.4: Inductor and filter details for Module 1, the Transmitter**

maximum output, 12 volts are applied to the top of 1L3 and the r.f. probe is connected to the top of 1R10. The output should be in the order of 10 to 11 volts.

The power amplifier stage is added with the r.f. choke being wound on a small ferrite bead as shown in Fig. 1.4. The output of the whole transmit board may now be checked with the r.f. probe. Transisitors 1Tr1 and 1Tr3 take a common 12 volt line and 12 volts must be applied to 1Tr2 at the top of 1L3, as it will be when the transmitter is keyed. The p.a. stage requires a dummy load for the test, in fact the transmitter should not be operated without a load for the sake of the health of 1Tr3! A suitable load can be made from a non-inductive resistance of around 50 ohms. Two 100 ohm, 2 watt, carbon resistors in parallel would be suitable. Connect the r.f. probe across the dummy load to check the output of the p.a. The output will depend upon the DRIVE control, and could be in excess of 3 watts output with high drive. Rough equivalent readings to r.f. output in watts are: 3 watts output about 21 volts, 2 watts output about 17 volts, 1 watt output about 12·5 volts.

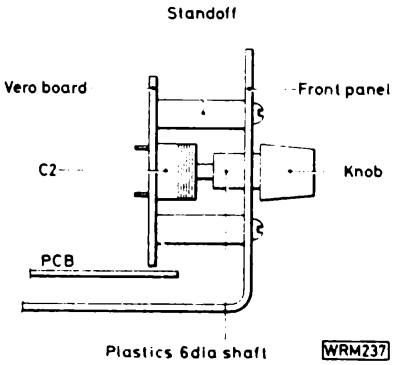
The low-pass filters are constructed from the chart in Fig. 1.4. The basic transmit board requires a filter for 7MHz and 14MHz. These are selected by a double-pole, change-over, miniature toggle switch, 1S1. The connections between the p.a., the switches and filters must be made with screened leads. The transmit board is capable of use on the 10·1MHz band with a suitable crystal and setting of 1C3. Although this band will not be used in the final project, values for the 10·1MHz band are given in the chart in Fig. 1.4 should the constructor wish to use the basic transmit module on this band.

The change-over and control circuit around 1Tr4 and 1Tr5 is best built and tested with a voltmeter before being used to control the transmitter. The relay, 1RLA/2, is a small 12 volt, 2-pole, change-over, relay with coil resistance around 185 ohms. When the circuitry around 1Tr4 and 1Tr5 has been completed and power applied, operating the key should cause the relay to come in when keying begins. The relay should remain closed until keying is stopped. Using the stated value for 1C14, the relay still remains closed at keying speeds as low as 8 words per



**G-QRP Club**

**A specialist group for users and builders of Low Power Equipment. Details from: Fred Garrett G4HOM, 47 Tilshead Close, Druids Heath, Birmingham B14 5LT.**




WRM237

**Fig. 1.5: Using a semi-airspaced trimmer for the VXO control (see text)**

minute. Also check that as the key is operated 12 volts appears at the collector of 1Tr4 in sympathy with the keying action. The interconnections for the control system can now be added. The antenna change-over section must be wired with screened leads and the 12 volt lines, +12V, 12 RX, 12 TX and 12 KEY are connected to a 5-pin DIN Socket, as shown in Fig. 1.1, for control lines in future modules. The transmit/receive indication l.e.d.s are mounted in small holes in the front panel.

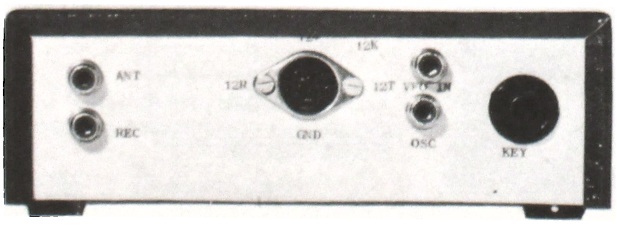
When the receiver module is added, it requires oscillator injection from the transmitter board. If this module is to be built later it is best to add the oscillator output socket when building the transmit module. The circuitry required is shown in Fig. 1.2(a). The oscillator output is taken from the top of 1R5 via a 10pF capacitor and screened lead to an output socket. All the signals leads in the PW "Teme" use the small standard phono plugs and sockets which are cheap and more than adequate for the purpose.

The photographs show the module layout. One standard case is used to house each module through the whole project, this being the inexpensive J6 Instrument Case sold by Minffordd Engineering. This case measures 152 × 102 × 51mm (6 × 4 × 2in) has an aluminium base and front/back panels with a pvc coated lid. The type I used had a rich deep brown pvc coated lid. I therefore used a lighter tone brown for the front panel. The front panel is made in the manner I have used for many years to give an attractive finish. When the front panel has been drilled to hold the controls, these are then removed. A piece of suitable thin card (pale brown in my example) is cut to fit the front panel. The positions of the holes are marked on the reverse of the card and cut out with a small pair of pointed scissors or modelling knife. The lettering is added with rub-down letter transfers and the card is lightly attached to the metal panel with "Pritt" glue. The whole front panel is then covered with a layer of transparent sticky-backed plastics film, of the sort used to cover books. This provides a durable, attractive finish and protects the lettering. A sharp knife removes the surplus plastics film from the holes and the controls are replaced. Care must be taken when tightening up control mounting screws not to bear down too tightly upon the plastics film and cause unsightly wrinkles. The whole effect is smart and durable and far superior to the usual amateur application of car aerosol paint and lettering. Constructors using dark coloured, or black, front panels could use the excellent water slide transfers of amateur radio legends which are now available for front panels.

## Using the Transmit Module

The transmitter may be used as a viable QRP rig in conjunction with an existing receiver. The receiver interconnects with the transmitter via the change-over circuitry for antenna, transmitter and receiver. The receiver may require some form of internal muting, although at these power levels just changing over the antenna and turning down the gain controls may be enough. In fact this method allows the receiver to monitor the keying of the transmission. One problem is that in the circuit shown in Fig. 1.2 the oscillator stage is on the whole time and may be heard on the receiver during reception. This can be solved by making use of the link in the printed circuit board between the top of 1R3 and the +12 volt line. Remove this link and connect the top of 1R3 to the 12 TX line. This will mean that the oscillator is only switched on when the transmitter is in the transmit mode. This connection must be restored to the original circuit arrangement when the transmitter is used in conjunction with the later modules.

Operating a low-powered transmitter on the amateur bands can be great fun. Added to the challenge is the satisfaction that the transmitter is home-made. Although the signal is likely to be some two S-units down on the average UK amateur signal, the user will soon be surprised what can be worked at these power levels. The transmitter is designed for a 50 ohm termination and like most modern transmitters must be used into an antenna with a characteristic impedance of 50 ohms, such as dipole or beam, or matched to the antenna with an antenna tuning unit (a.t.u.). The vxo control should give enough frequency offset to allow stations slightly off the fundamental frequency of the crystal to be called. QRP operation can be very addictive as the 2000-plus members of the G-QRP Club will confirm. For the low outlay, this little transmitter module should provide a lot of enjoyment. ●




**A rear-panel view of the completed Transmitter module**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**DEVOTED TO LOW POWER COMMUNICATION**

If the idea of QRP operation appeals to you, and you would like to pursue it further, why not join the G-QRP club, a specialist group for users and builders of low power equipment.

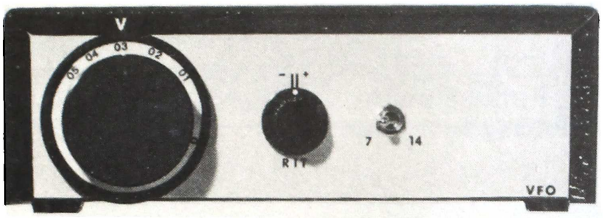
Details from:-

**Fred Garrett, G4HOM,**
**47 Tilshead Close,**
**Druids Heath,**
**Birmingham B14 5LT.**

# PW 'TEME' Modular QRP Transceiver

THIS MONTH - VARIABLE FREQUENCY OSCILLATOR

Part 2 by Rev. George Dobbs G3RJV




The first part of this series described the construction of a useful little transmitter module for the 7 and 14MHz bands. Although capable of useful excursions on the amateur bands, the transmitter is VXO controlled. That is, the oscillator frequency source is a crystal with a small range of adjustment in frequency. It is much more exciting to be able to take the transmitter anywhere on the c.w. portion of the band to find contacts. The module to be described here is an add-on variable frequency oscillator (v.f.o.) and doubler that allows the whole of the 7 or 14MHz c.w. bands to be used with the transmit module. The v.f.o. doubler module matches the transmit module and can be stacked on top of it with interconnecting leads at the back of the cases.

## VFO/Doubler Circuit (Module 2)

The circuit is shown in Fig. 2.1. A lot has been written about the design of variable frequency oscillators and many amateurs have tales of woe about drifting, jumping or chirping oscillators. Experience has shown me that, provided a few sensible rules are observed, the average amateur can easily build a stable, reliable v.f.o. Stability usually has more to do with the way the oscillator is built rather than the circuit employed, but more about that later. This v.f.o. has a standard Colpitts f.e.t. oscillator, 2Tr1, followed by an f.e.t. buffer amplifier, 2Tr2. The tuning circuit inductor, 2L1 (see coil chart in Fig. 2.2), uses a conventional coil former of 4·8mm ($\frac{3}{16}$ in) diameter with an iron dust core. Many constructors eschew the use of cores in v.f.o. tuning coils in the interests of stability. But a core is a very convenient way of adjusting the frequency of the circuit when setting up the v.f.o. In practice, trimming and padding with capacitors can cause just as many problems as including a core in the coil former. The value of 2L1 is such that only a small portion of the core needs to enter the windings to adjust the frequency. It is stable.

The output from the v.f.o. is on 7MHz as is the buffer amplifier. The output from the buffer, 2Tr2, is tuned at 7MHz by 2L2 and 2C10. The 7MHz output from the buffer is taken from the collector of 2Tr2 via 2C11. This output is switched against the 14MHz output from the doubler.

The doubler uses a balanced push-pull circuit. Many other types of circuit could be used and indeed were tried. A doubler requires good suppression of the fundamental, a reasonable output and low spurious outputs. Integrated circuit doublers were tried but rejected for lack of simplicity in what is designed to be a simple project, and diode doublers, although clean in operation, give very low outputs. The best practical circuit proved to be the one shown in 2Tr3 and 2Tr4 of Fig. 2.1.

The centre-tapped coil 2L3 is a link winding around 2L2 and provides signals 180° out of phase for the inputs of 2Tr3 and 2Tr4. Potentiometer 2R8 is a preset variable resistance used to balance the output which appears on the collectors of 2Tr3 and 2Tr4. Coil 2L4 with 2C17/18 tune out the 14MHz signal. The tuned circuit on the output is damped by R9 to give broadband characteristics. The capacitance in the output tuned circuit, provided by 2C18 and 2C17, is split to lower the impedance of the output signal. It is commonly assumed that an oscilloscope is essential for setting up push-pull doubler circuits. That is the ideal method, if one has an oscilloscope that can see 14MHz, but adequate balancing can be obtained using a diode r.f. probe and a meter.

One of the very useful facilities that can be added to a variable frequency oscillator in a transceiver is receiver incremental tuning (r.i.t.). This allows a small degree of independent tuning to be added to the v.f.o. during receive conditions, to tune in stations slightly off the transmit frequency. Another name used for such a control is a clarifier. The r.i.t. facility has been added to this circuit in anticipation of the receiver module to be added later. Even without the receiver module, when the transmitter is being used with a separate receiver this facility will still be used to offset the transmit signal on receive.

The offset tuning is achieved by 2C20 and 2D1 which add capacitance across the tuned circuit of the v.f.o. Diode 2D1 is a Varicap diode, the capacitance of which varies with the amount of d.c. bias voltage applied. The voltage to set the capacitance, and hence the frequency of the v.f.o., comes from a choice of voltages controlled by variable resistors. The frequency-determining components, 2C20 and 2D1, are part of the structure of the v.f.o., and to prevent long leads affecting the stability of the oscillator, the d.c. voltage is r.f.-decoupled by 2L5 and 2C21. Differing voltages are applied to the v.f.o. on transmit and receive by the 12TX and 12RX control lines

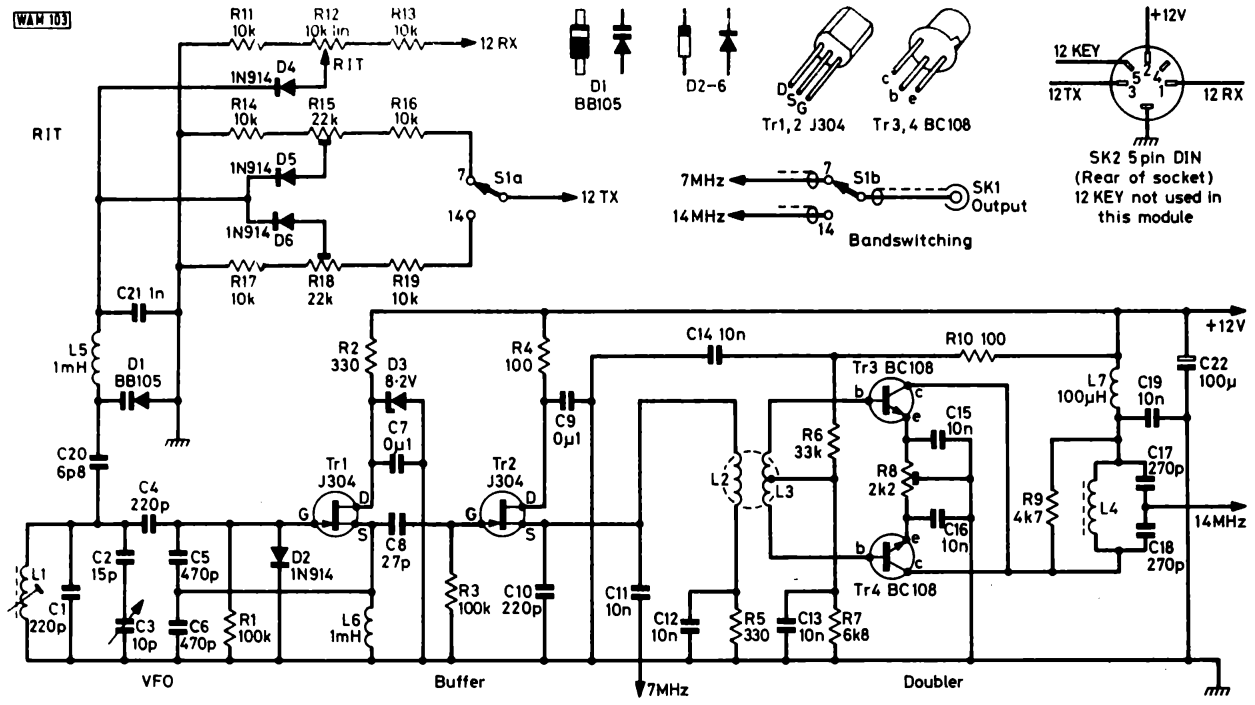



**Fig. 2.1: Circuit diagram of Module 2, the VFO/Doubler**

available from the transmit module. On transmit the voltage is preset by either 2R15 or 2R18 and on receive a front panel control, 2R12, comes into use to give a manual offset of the frequency. If 2R15 and 2R18 are set to about mid-travel on transmit, the RIT control 2R12 will allow tuning either side of the transmit frequency. Separate presets are required for the 7 and 14MHz bands so that the RIT control can be set to the same position on both bands to equalise the transmit and receive frequencies.

## Construction

The v.f.o. and doubler are built on one board and housed in a Minffordd J6 case. The layout of the board is shown in Fig. 2.3. Good construction techniques are essential in building variable frequency oscillators. Most of the problems associated with oscillators built by amateurs may be traced to poor construction. The circuitry around the oscillator stage must be firmly and securely built so that no components or leads can move about. The purists write about the use of NPO capacitors in v.f.o. tuned circuits but I can never get hold of them when I want them. For most practical purposes polystyrene types of good quality are also capable of good results. In the v.f.o. circuit 2C1, 2C4, 2C5 and 2C6 are polystyrene. Because of their values, 2C2 and 2C20 had to be silvered mica and this type of capacitor was also used in 2C8, 2C10, 2C17 and 2C18.

The tuned circuit section must be carefully and sturdily built. Coil 2L1 is made from details shown in Fig. 2.2. The method of mounting the slow motion tuning drive for 2C3 is shown in Fig. 2.4(a). A direct drive on 2C3 would give too rapid a tuning rate, so a small in-line epicyclic reduction drive is used. This is attached to the front panel and a bent aluminium bracket holds the control shaft of 2C3. Just behind the 6mm (¼in) shaft which takes the knob is a collar which moves at the same rate as the reduced drive. Usually these drives give a reduction of some 6 to 1. Onto this collar is mounted a tuning scale, marked with frequency divisions. Almost any disc could be used for the dial; the prototype used the top from a Colman's Mustard jar, cut down and sprayed with matt black paint. The scale is made from white card glued on the front of the disc.

The buffer stage may then be built as far as 2L2/3, which is wound to details given in Fig. 2.2. An iron dust toroid core must be used for 2L2/3; most surplus toroids (being ferrite) would not be suitable. The winding 2L3 is wound over 2L2 and has a centre tap. Wind on half of the winding, twist out a little of the wire and then wind on the rest. The whole assembly fits onto the printed circuit board as shown in Fig. 2.3.

When completed as far as 2L3, the buffer and oscillator stages may be tested for their 7MHz output. Using the r.f. probe described in Part 1 of this series, the r.f. output is measured from the top of 2L2. It should be around half a volt. The signal may be listened for on a receiver. This will give an opportunity for an initial setting of the core in 2L1 to reach the band edge (7·0MHz) with the vanes of 2C3 closed. The core will require re-adjustment when all the stages are completed.

The remainder of the circuit board is completed by adding the circuitry around 2Tr3 and 2Tr4. Ideally the output from the doubler should be balanced, using 2R8, by observing the waveform on an oscilloscope. What this achieves is to balance 2Tr3 and 2Tr4 so that the combined outputs at 2L4 are equal. This can also be done with the simple diode r.f. probe and a meter. Read the r.f. voltage from the 14MHz output at the junction of 2C17 and 2C18. Adjust 2R8 for the minimum output and the balance should be just about correct. The value of 2R8 has been chosen to give a similar r.f. output from the doubler and the buffer output points. If the doubler output reads higher it is probably due to the frequency-conscious nature of the r.f. probe.

The r.i.t. circuitry and switching is added as shown in the layout drawing in Fig. 2.4(b). The switch which selects the 7 or 14MHz output is also used to select the voltage

## BUYING GUIDE

J304 field effect transistors may be obtained from J. Birkett, 25 The Strait, Lincoln (0522) 20767.

Coil formers suitable for 2L1 are the Maplin type 722/2.

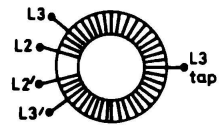
Please note the toroids are iron powder, **not** ferrite cores. Most unmarked surplus toroid cores are ferrite.

See also the Buying Guide in Part 1 of this series.

**Approximate Cost** £27

**Construction Rating** Intermediate

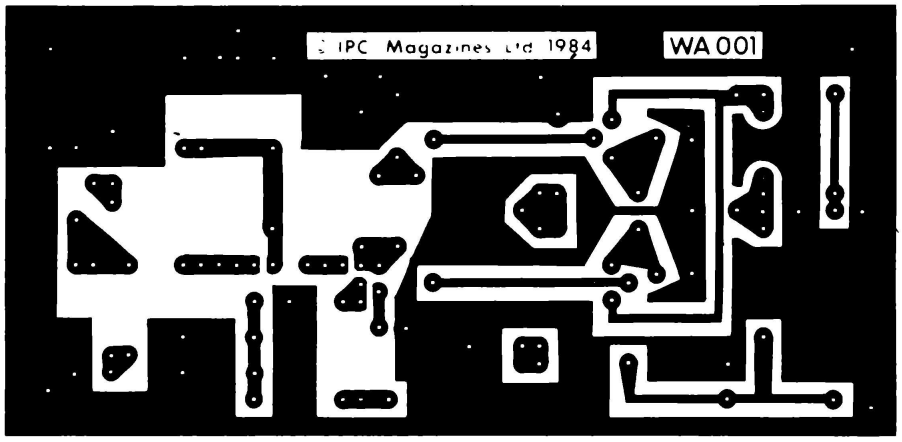
| |
|---|
| L1 = 20 turns 28 swg. enamelled wire on 4·8mm dia. former with core |
| L2 = 23 turns 26 s.w.g. on T50-6 core |
| L3 = 20 turns 26 s.w.g. (centre tapped) over L2 |
| L4 = 14 turns 22 s.w.g. on T50-6 core |




WAM 104

**Fig. 2.2: Coil winding details for the VFO/Doubler module**

for the offset on transmit for 7 and 14MHz. It should be possible to check the effectiveness of the r.i.t. circuit by listening for the signal on a receiver and adjusting 2R12. The setting up of 2R12, 2R16 and 2R18 is not critical at this stage as they are only required when the receiver module is added. But if the transmitter and v.f.o. are to be used in conjunction with a separate receiver, the v.f.o. will be heard during the receive periods because it is switched on the whole time. It is not a good idea to keep switching the v.f.o. on and off as this will certainly mean instability. Although the oscillator is stable, like most f.e.t. oscillators, there is an initial warm-up drift as the f.e.t. junction attains a stable operating temperature. In the transmit board, the



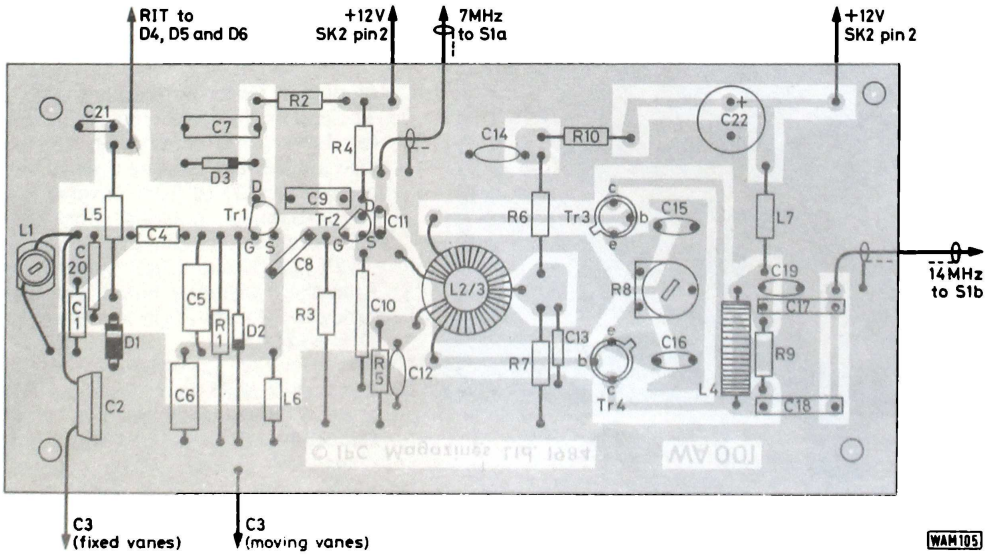




**Fig. 2.3: Full size p.c.b. track pattern and component layout for Module 2, the VFO/Doubler**

## ★ components

**MODULE 2**
**VFO/DOUBLER**

**Resistors**

*½W 5% carbon film*

| | | |
|---|---|---|
| 100Ω | 2 | R4,10 |
| 330Ω | 2 | R2,5 |
| 4·7kΩ | 1 | R9 |
| 6·8kΩ | 1 | R7 |
| 10kΩ | 6 | R11,13,14, 16,17,19 |
| 33kΩ | 1 | R6 |
| 100kΩ | 2 | R1,3 |

*Sub-min. horizontal pre-set*

| | | |
|---|---|---|
| 2·2kΩ | 1 | R8 |
| 22kΩ | 2 | R15,18 |

*Lin. law pot., ¼in spindle*

| | | |
|---|---|---|
| 10kΩ | 1 | R12 |

**Capacitors**

*Polystyrene or silvered mica*

| | | |
|---|---|---|
| 6·8pF | 1 | C20 |
| 15pF | 1 | C2 |
| 27pF | 1 | C8 |
| 220pF | 3 | C1,4,10 |
| 270pF | 2 | C17,18 |
| 470pF | 2 | C5,6 |

*Variable, airspaced*

| | | |
|---|---|---|
| 10pF | 1 | C3 |

**Inductors**

*Min. axial r.f. chokes*

| | | |
|---|---|---|
| 100µH | 1 | L7 |
| 1mH | 2 | L5,6 |

L1–L4 see text and Fig. 2.2

*Ceramic*

| | | |
|---|---|---|
| 1nF | 1 | C21 |
| 10nF | 7 | C11–16,19 |

*Polyester*

| | | |
|---|---|---|
| 0·1µF | 2 | C7,9 |

*Electrolytic, 25V p.c. mounting*

| | | |
|---|---|---|
| 100µF | 1 | C22 |

**Semiconductors**

*Transistors*

| | | |
|---|---|---|
| BC108 | 2 | Tr3,4 |
| J304 | 2 | Tr1,2 |

*Diodes*

| | | |
|---|---|---|
| BB105 | 1 | D1 |
| 1N914 | 5 | D2,4,5,6 |
| BZY88C8V2 | 1 | D3 |

**Miscellaneous**

Phono socket; 5-pin DIN socket; Switch, d.p.c.o. min. toggle; Slow-motion drive, 6:1 in-line epicyclic type (for C3); Printed circuit board; Case, Minffordd J6; Feet, knobs (2), dial, etc.

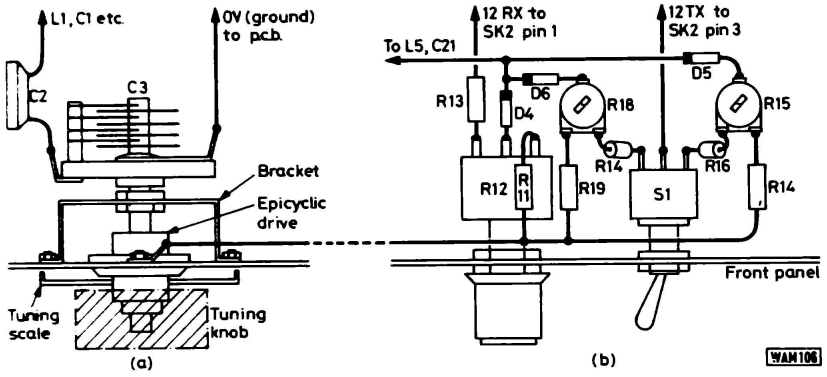
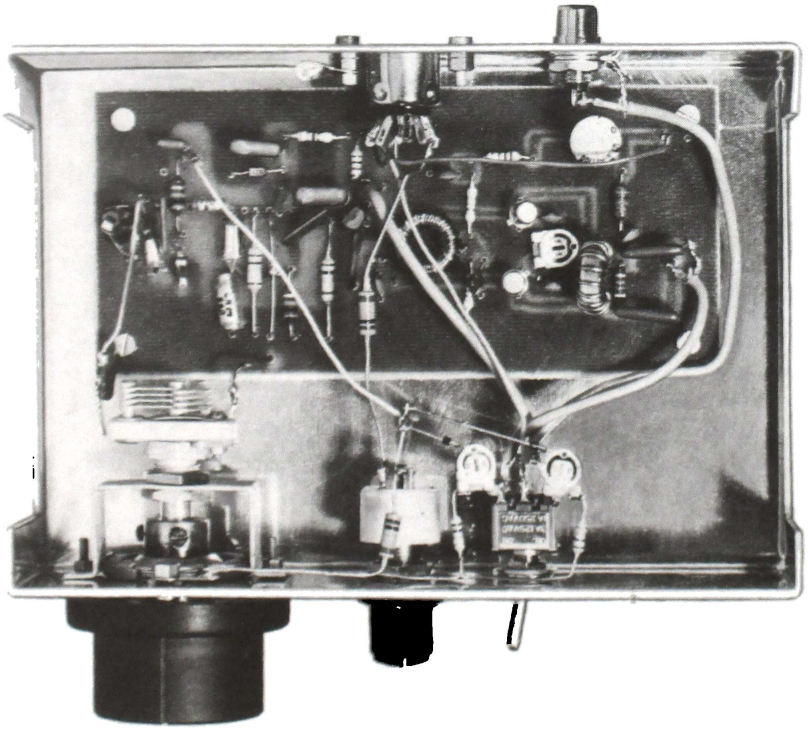



**Fig. 2.4: (a) Slow motion tuning drive assembly. (b) Wiring of the RIT and BANDSWITCH controls**



oscillator stage was arranged to switch on only in the transmit mode. That stage is now being used as a predriver on the transmit chain and the link in the printed circuit board must be restored to place 12 volts on the stage and the 12TX line removed.

A good way to prevent the v.f.o. being heard in the receiver during receive conditions is to offset the frequency of the v.f.o. out of the passband of the receiver. This can be done by setting 2R15 and 2R18 at one end of the preset travel and 2R12 at the other end of its travel. This will mean that the r.i.t. is set to give the maximum offset of the oscillator between transmit and receive. The oscillator should now be far enough away from the transmit frequency (to which the receiver is tuned) not to be heard on the receiver.

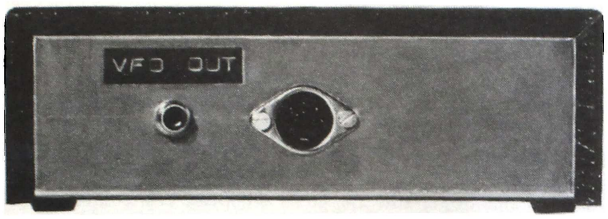
The layout for the v.f.o./doubler module is shown in the photographs. The case is the same type as that used for the transmit module. The finish is also applied in the same manner with a cardboard false front covered with sticky-backed plastics film. The v.f.o./doubler circuit requires the +12V, 12TX and 12RX control lines from the transmitter board which are brought into the case via the 5-pin DIN socket.

The v.f.o. is connected to the transmit module using the 5-pin DIN control line leads plus a single screened lead, terminated with phono plugs and sockets, which takes the signal from the v.f.o. case to the transmitter case. The changeover from transmit to receive is controlled

To avoid confusion between the several modules making up the PW "Teme" project, each has been numbered as follows:

| | |
|---|---|
| Transmitter | Module 1 |
| VFO/Doubler | Module 2 |
| Receiver | Module 3 |
| ATU and SWR Bridge | Module 4 |
| Power Supply | Module 5 |
| Digital Clock | Module 6 |

Each drawing and components list will state which module number it refers to. In the text, component references will be prefixed by the module number. For example, resistor R9 in the Transmitter Module would be called 1R9, while R9 in the Receiver Module would be 3R9.



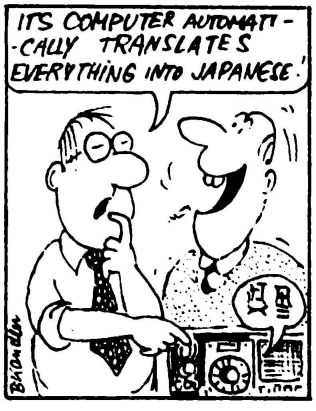

**Rear view of the completed VFO/Doubler module**

by the transmit board and the antenna and receiver are connected exactly as if using the transmit board in its basic form. The v.f.o./doubler arrangement will give somewhat less output from the transmitter than the crystal oscillator, but the drive control ought to be able to give at least 3 watts of r.f. output on both bands.

The resulting transmitter will now cover the whole c.w. portions of the 7 and 14MHz bands. The transmitter will have to be netted to the station to be called by depressing the key, to defeat the r.i.t. offset. This transmitter should be capable of quite exciting results on 7 and 14MHz. Low power (QRP) stations usually congregate around 7030kHz or 14 060kHz and it is worth calling "CQ QRP" on these frequencies from time to time. Other than that, the best results with low power are rarely obtained by calling CQ. Seek stations out, instead, and call them. Some of the best QRP contacts can be had by "Tail-ending" an existing QSO and quickly calling one of the stations at the end of their contact. Have a go—it is fun!

**Benny**

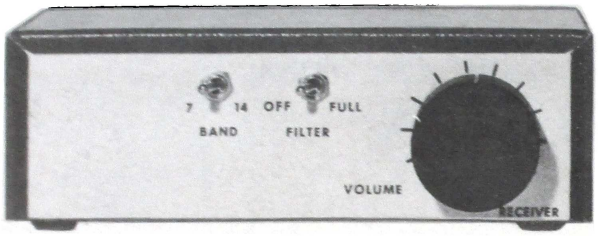
SYNCHRONOUS DETECTOR FREQUENCY SYNTHESIS DIGITAL READOUT, MUTE SQUELCH, VARIABLE BANDWIDTH, LSB, USB, MEMORY SIDETONE, DIGITAL WATCH, SPACE INVADERS...



THIS MONTH-
THE RECEIVER

# PW 'TEME' Modular QRP Transceiver

Part 3 by
Rev. George
Dobbs G3RJV




Of all the projects that a radio amateur can build, a receiver probably rates as the most satisfying. Even the most seasoned constructor still thrills to the sound of the first signals emanating from a newly completed receiver. Remember the days when you dragged your hapless parents up to your room and clamped a pair of headphones around their ears to listen to the sounds of your first crystal set? No?—Well I suppose some people have to miss the formative experiences of life. This series of articles began with a basic transmitter module, to which was added a variable frequency oscillator. Used in conjunction with the receiver described here, these will give full transceive facilities.

## The Circuit

The receiver section uses the existing variable frequency sources on 7 or 14MHz from the transmitter sections of the project in a Direct Conversion Receiver. Direct conversion receivers are the simplest way to make a transceiver from a transmitter. The incoming signal is mixed with the local oscillator from the transmitter and the audio difference between the signals is amplified for reception of c.w. or s.s.b. signals. So the arrangement is simply a product detector followed by audio amplification. Perhaps it could be called a superhet receiver with zero intermediate frequency. Without intermediate frequency stages, which is where the majority of the selectivity and gain is produced in a superhet, direct conversion receivers do have inherent problems. The gain usually comes from the audio stages and the selectivity must either come from audio filtering or tight front-end input tuning, or both. This module attempts to overcome the worst shortcomings of direct conversion by having good input tuning, high audio amplification and narrow audio frequency filtering.

A block diagram of the receiver module is shown in Fig. 3.1. The incoming signal to be received ($f_i$) is tuned in an r.f. stage and mixed with the signal from the transmitter board local oscillator ($f_o$). If the signals are some 750Hz apart the mixed difference between the signals will appear at the output of the mixer. Both signals are taken from the transmit board; the oscillator from the tuned predriver stage and the input signal from the transmit/receive changeover relay. The audio signal is passed through an active audio c.w. filter, which can be switched to wide or narrow positions, and thence to a volume control, the only adjustable control on the receiver module. The audio filter is a bandpass circuit for signals of 750Hz, a good listening tone for a c.w. signal. An integrated-circuit audio amplifier provides output for headphones or a small loudspeaker.

The receiver module has a small sidetone oscillator. This is to provide an audio tone to monitor the transmit keying. Such an oscillator is essential for those of us who find it difficult to send Morse without hearing the results. The sidetone oscillator is powered by the 12 KEY line available from the transmitter module. The front-end of the receiver, the r.f., mixer and filter stages, is powered by the 12 RX line which is only present in the receive mode but the audio amplifier is powered by the +12V line so that the sidetone can be amplified during transmission.

The complete circuit is shown in Fig. 3.2. Avid readers of *PW* will recognise the input and mixer sections of the receiver board as being the same circuitry as used in the author's *PW* "Severn" (see page 17). Many types of mixer could have been used but for cheapness and good overall performance this mixer circuit was pressed into service again. It uses three field-effect transistors in a Y configuration with 3Tr2 and 3Tr3 being a balanced mixer and 3Tr1 an r.f. amplifier feeding the source connections

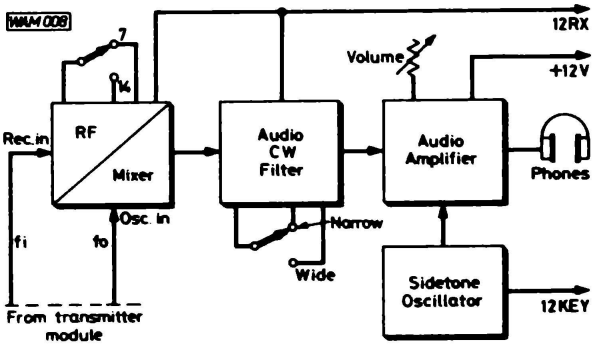



**Fig. 3.1: Block diagram of Module 3, the Receiver**



*Reprinted from Practical Wireless, January 1985*

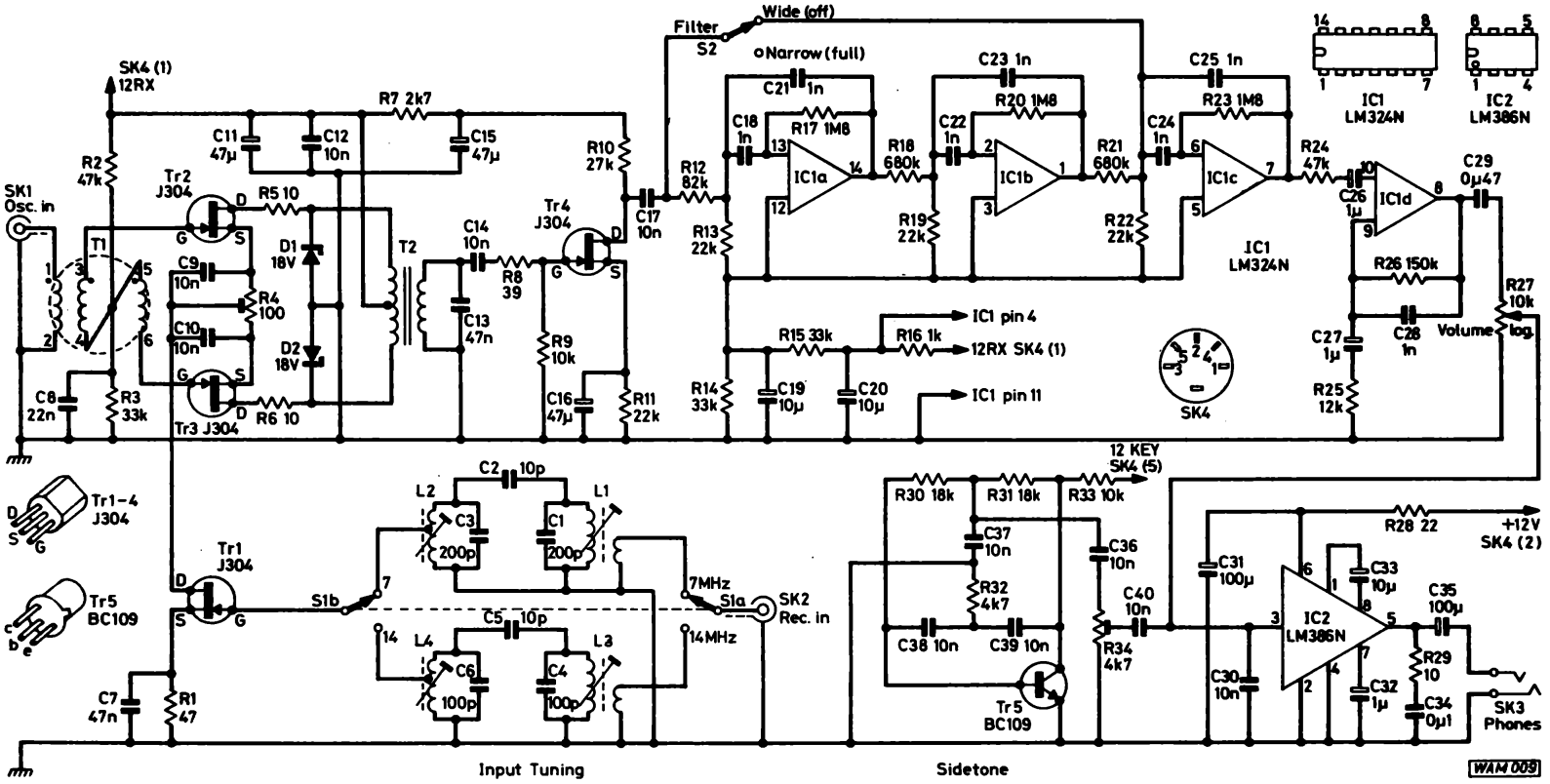



Fig. 3.2: Circuit diagram of Module 3, the Receiver

of 3Tr2 and 3Tr3. Transistors 3Tr2 and 3Tr3 are balanced by 3R4 and their outputs feed into a transformer 3T2. Two 18 volt Zener diodes, 3D1 and 3D2, prevent high-voltage transients from 3T2 damaging the transistors. The r.f. stage, 3Tr1, is switched between input tuned circuits for 7 or 14MHz. The input filters are bandpass-tuned pairs of tuned circuits loosely top-coupled with 3C2 or 3C5. The mixer transistors 3Tr2 and 3Tr3 require a balanced input from the oscillator and this is provided by trifilar-wound broadband ferrite transformer, 3T1.

The output from 3T2 is decoupled by 3C13 and coupled by 3C14 into an f.e.t. audio pre-amplifier, 3Tr4, which feeds the filter circuitry around a quad operational amplifier 3IC1, the common LM324N. Three sections of this i.c. provide bandpass filtering at 750Hz, with switched options for all three stages or only the final stage. The fourth section, 3IC1d, drives the audio amplifier 3IC2 via the volume control, 3R27. The actual bandwidth of the filter has not been objectively measured but with all the filtering stages switched in, it operates as a very worthwhile c.w. filter. The LM324 proved its worth in this circuit providing four well-isolated stages at low current consumption.

The LM386 is a useful small i.c. audio amplifier designed to feed an 8 ohm output. The quiescent current is low and the output in the order of half a watt. The LM386 is a better alternative in the cheap price range (around £1.00 each) to the more popular, but less stable and more noisy, LM380. The sidetone oscillator circuit is a basic one-stage phase-shift audio oscillator keyed by the 12 KEY line. Unijunction sawtooth oscillators or 555 i.c. squarewave oscillators are probably more common in simple sidetone circuits, but the few extra components of this circuit are worth the effort for the pleasant sinewave tone. A soothing sidetone can make for more comfortable operating than a rasping tone from a simple oscillator.

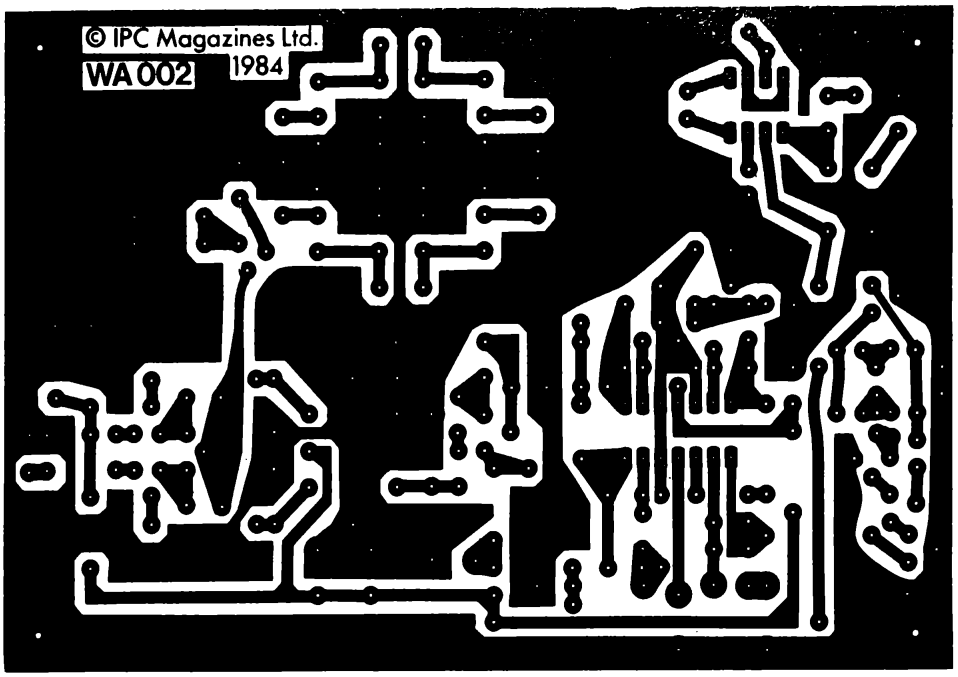
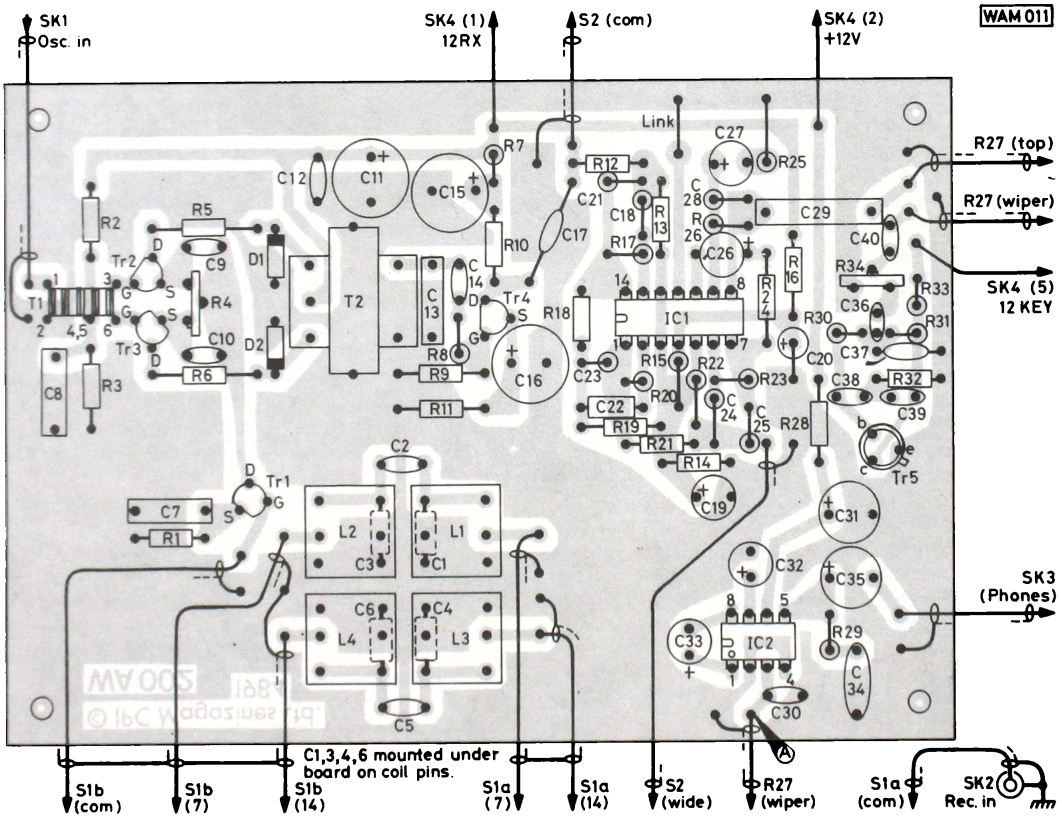



**Fig. 3.3.: Full size p.c.b. track pattern and component layout for Module 3, the Receiver**




## Construction

The whole receiver module is built on one printed circuit board as shown in Fig. 3.3. Receiver circuits are best built beginning at the audio output and working towards the inputs so that some intermediate testing of the circuit elements can be done. The circuit around the audio amplifier section, 3IC2, may be built as far back as the volume control, 3R27, and tested as an audio amplifier. With +12 volts applied at the top of 3R28, and a pair of suitable headphones or a small 8 ohm speaker attached to the output, the amplifier may be tested using an audio source or just by placing a finger onto the top of 3R27 and listening for hum. Check that 3R27 is wired the correct way round so that volume increases as the control is turned clockwise. The sidetone oscillator can be built next and tested by applying the output to point A on the circuit for 3IC2. Preset potentiometer 3R34 is adjusted for a comfortable sidetone level, and this is independent of the setting of the main volume control.

The filtering section 3IC1 is arranged to give as much audio gain as possible without instability. The stages may be built in reverse order: 3IC1, d, c, b, a; and each stage tested in turn. The gain of the section is such that without its input connected to 3Tr4, the whole filter may oscillate when tested. This oscillation should cease when 3Tr4 is added. The overall gain of the filter section can be changed by altering 3R25. When the whole receive section is built 3R25 could require some individual adjustment. It is set to give maximum gain whilst retaining stability and it should be possible to turn 3R27 to maximum without the receiver audio stages oscillating. This may well require adjustment for some types of headphones.

When 3Tr4 has been added, the rest of the circuit must be completed for testing. Transformer 3T2 is a small audio-frequency type as used for driving push-pull output stages in transistor radios, but used in reverse. The LT44 driver transformer is suitable for this application but it may be possible to cull a suitable transformer from an old transistor radio with a push-pull output stage. The impedance ratio is some 20kΩ to 1kΩ or 2kΩ, centre-tapped. Ensure that the connections for 3Tr2 and 3Tr3 are correctly wired with the source leads connected to 3R4 and the drain leads to 3R5 and 3R6.

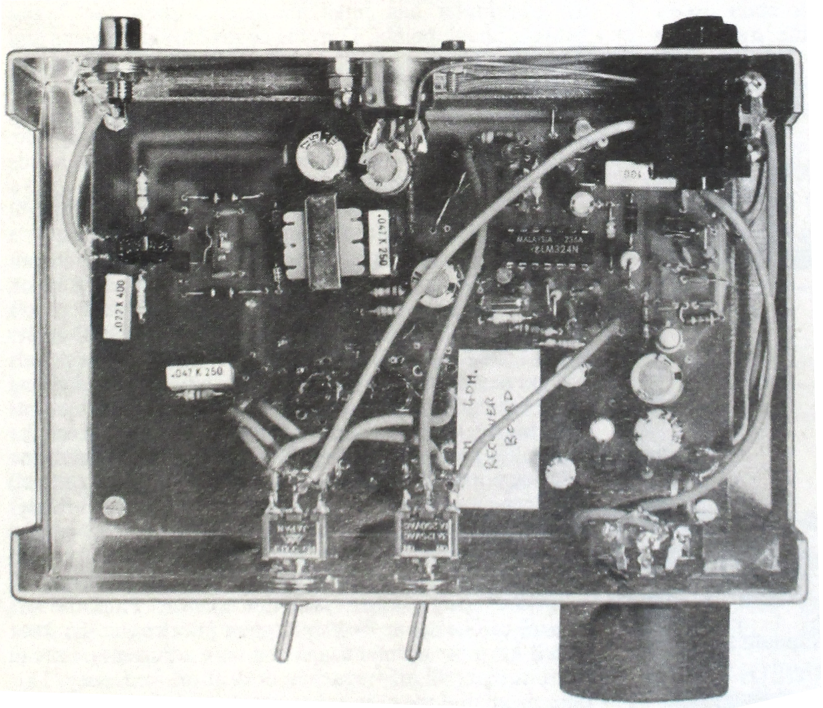
The winding details for the inductors are shown in Fig. 3.4. The most complex winding is the trifilar winding for the oscillator input transformer, 3T1. Although a T37–43 ferrite core is quoted in the chart, most similar ferrite cores of approximately 13mm ($\frac{1}{2}$in) outside diameter would do the job. Cut three lengths of 32s.w.g. enamelled wire (or 28s.w.g. if the former is large enough) long enough to give 12 turns around the core. Twist the three wires together to give around 8 twists per inch and wind the combined wires around the core for 12 turns. Identify the start and finish of each wire with an ohmmeter and connect into the circuit following the configuration shown in Figs. 3.4 and 3.2. The dot on each winding marks the beginning of that winding.

The input tuned circuit coils, 3L1 to 3L4, are wound on 4·8mm (3/16in) formers with an iron dust core. This former is part of an assembly which includes a base and a screening can. A suitable commercial type is suggested in Fig. 3.4 but it may be possible to obtain surplus formers and cans of this type. They are very common in the surplus market. The coils are close-wound on the former, and short stiff wires soldered onto the base pins rise vertically up the sides of the former to provide connection points for the windings. The capacitors 3C1, 3, 4 and 6 which form part of the tuned circuits are miniature ceramic plate types soldered directly under the pins of the coil bases. The leads around the bandchange switch, 3S1, must be wired in screened cable. Miniature coaxial cable is ideal although the commoner thin microphone cable can be used. The final wiring is to add the input and output connections to the board. Phono sockets are used for receiver and oscillator input, a $\frac{1}{4}$in jack socket for the headphone connection and the +12V, 12RX, and 12 KEY lines are picked up in a 5-pin DIN socket from the other modules.

The receiver module, like the other modules, is built into a Minffordds J6 Instrument Case. The layout for the case is shown in the photographs. The front panel has only three controls. Miniature toggle switches provide the band selection and the filter bandwidth choice, whilst the volume control, 3R27, is controlled by a large knob. (In the prototype the same type of knob as used for the v.f.o. tuning control.) This means that the two most frequently used controls on the transceiver are large and easy to handle.

## Setting-Up

The receiver module requires a simple setting-up procedure to be completed before it can be used. The constructor must first ensure that the value chosen for 3R25 will allow the volume control, 3R27, to be turned up full without the audio stages oscillating. The d.c. operating condition of the three f.e.t.s in the mixer/r.f. stages must also be balanced. The value of 3R3 has been chosen to give equal voltages across the upper transistor pair (3Tr2–3) and the lower transistor (3Tr1). With no input from the oscillator, a meter on the drain circuit of 3Tr1 should show half the total voltage across the three f.e.t.s.



L1 = 22 turns 26 s.w.g., link winding 4 turns 26 s.w.g.

L2 = 22 turns 26 s.w.g., tap at 17 turns

L3 = 14 turns 26 s.w.g., link winding 4 turns 26 s.w.g.

L4 = 14 turns 26 s.w.g., tap at 10 turns

L1–L4 All wound on 4·8mm ($\frac{3}{16}$ in) diameter formers (Maplin 722/1 or similar), with dust core, base and can.

T1 = 12+12+12 turns 32 (or 28) s.w.g. trifilar wound on T37-43 or similar ferrite core

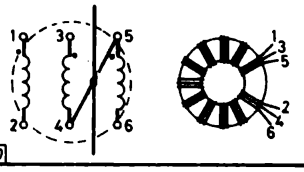



**Fig. 3.4: Coil winding details for the Receiver module**

## ★ components

**MODULE 3 RECEIVER**

**Semiconductors**

*Transistors*

| | | |
|---|---|---|
| BC109 | 1 | Tr5 |
| J304 | 4 | Tr1–4 |

*Diodes*

| | | |
|---|---|---|
| BZY88C18V | 2 | D1, 2 |

*Integrated circuits*

| | | |
|---|---|---|
| LM324N | 1 | IC1 |
| LM386N | 1 | IC2 |

**Inductors**

L1–4 and T1 see text and Fig. 3.4

T2 Maplin LT44 or similar (see text)

**Capacitors**

*Polystyrene*

| | | |
|---|---|---|
| 1nF | 7 | C18, 21–25, 28 |

*Ceramic plate*

| | | |
|---|---|---|
| 10pF | 2 | C2, 5 |
| 100pF | 2 | C4, 6 |
| 200pF | 2 | C1, 3 |
| 10nF | 11 | C9, 10, 12, 14, 17, 30, 36-40 |

*Polyester*

| | | |
|---|---|---|
| 22nF | 1 | C8 |
| 47nF | 2 | C7, 13 |
| 0·1µF | 1 | C34 |
| 0·47µF | 1 | C29 |

*Electrolytic, 25V p.c. mounting*

| | | |
|---|---|---|
| 10µF | 3 | C19, 20, 33 |
| 47µF | 3 | C11, 15, 16 |
| 100µF | 2 | C31, 35 |

*Electrolytic, 63V p.c. mounting*

| | | |
|---|---|---|
| 1µF | 3 | C26, 27, 32 |

**Resistors**

*¼W 5% carbon film*

| | | |
|---|---|---|
| 10Ω | 3 | R5, 6, 29 |
| 22Ω | 1 | R28 |
| 39Ω | 1 | R8 |
| 47Ω | 1 | R1 |
| 1kΩ | 1 | R16 |
| 2·7kΩ | 1 | R7 |
| 4·7kΩ | 1 | R32 |
| 10kΩ | 2 | R9, 33 |
| 12kΩ | 1 | R25 |
| 18kΩ | 2 | R30, 31 |
| 22kΩ | 4 | R11, 13, 19, 22 |
| 27kΩ | 1 | R10 |
| 33kΩ | 3 | R3, 14, 15 |
| 47kΩ | 2 | R2, 24 |
| 82kΩ | 1 | R12 |
| 150kΩ | 1 | R26 |
| 680kΩ | 2 | R18, 21 |
| 1·8MΩ | 3 | R17, 20, 23 |

*Sub-min vertical pre-set*

| | | |
|---|---|---|
| 100Ω | 1 | R4 |
| 4·7kΩ | 1 | R34 |

*Log law pot., ¼in spindle*

| | | |
|---|---|---|
| 10kΩ | 1 | R27 |

**Miscellaneous**

Phono sockets (2); 2-pole ¼in jack; 5-pin DIN socket; Switch s.p.c.o. min. toggle; Switch d.p.c.o. min. toggle; Printed circuit board; Case, Minffordd J6; Feet, knob, etc.

This will prevent 3Tr2 and 3Tr3 running at too low a voltage and being driven into regions below their pinch-off point. The input tuned stages are set up with a suitable r.f. source, for example a calibrated signal generator, or simply by listening on the band and adjusting the cores of the coils for maximum signal. In each case adjust the coil closest to the r.f. transistor, 3Tr1, first.

The setting up of the input tuned circuits is not too critical. Although a signal generator is useful, I initially set up the circuits by ear with signals on the band and a later check with a signal generator proved that little extra adjustment was required. It is also possible to make use of crystals which may have been used if the transmitter module was operated in its basic form. These can be placed into a small oscillator circuit and used as a simple signal generator. The constructor unsure about what circuit to use, could build up a breadboard version of the crystal oscillator used in the transmit module. The balance control for the mixer, 3R4, is best set up last of all. Do the initial setting-up with the 3R4 preset to its mid-point and then adjust it for best results with weak signals received in normal operating conditions. Although subjective, "on-the-hoof testing" has the advantage of achieving the actual results that are being sought.

In use it is better to set up the tuning control on the transmitter module for a peak on receive rather than a peak on transmit. On the prototype the tuning control on the transmitter has small markers to show the 7 and 14MHz tuning points. Turn the control to these points and then carefully tune for maximum signal strength on the receiver, the transmitter will take care of itself. This is especially so in the case of the 14MHz band where tuning for maximum transmitter output can produce a nasty note in the receiver. It is very quick and easy to change bands and tune up, once this has been done a few times.

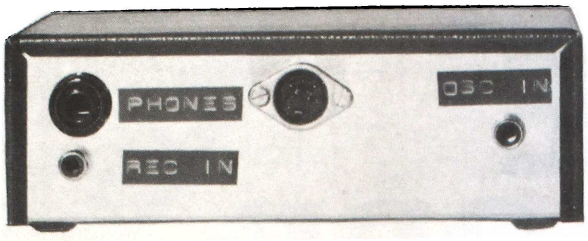
Now the receiver module is in use, the RIT control comes into its own. Before it can be used it requires a little careful setting up. The simplest way is to set the transmit frequency offset controls, the presets 2R15 and 2R18 on the VFO/Doubler circuit, to correspond with the centre point of the RIT control, 2R12 (also on the VFO/Doubler circuit). Because this is a direct conversion receiver signals will be heard both sides of the zero beat. The individual has a little choice in how the r.i.t. is arranged. The control may be set to correspond exactly with zero beat of the transmit signal by adjusting 2R15 or 2R18 to match the frequency for the band in question with 2R12 (RIT control) in its centre positon. Most direct conversion receiver users prefer to set the r.i.t. so that when the station to be worked is received at the audio frequency of the filter, the transmit frequency preset is adjusted so that the transmitted signal is on the exact frequency of that station. Thus the RIT control can be set at the centre point (marked on the front panel) for most normal usage and only adjusted to tune in stations that call off-frequency or drift off-frequency. This does mean that the user has to decide, before setting up the

## BUYING GUIDE

J304 field effect transistors may be obtained from J. Birkett, 25 The Strait, Lincoln, telephone (0522) 20767. See also the Buying Guide in Part 1 of this series

**Approximate Cost** £23

**Construction Rating** INTERMEDIATE




**Rear view of the completed Receiver module**

r.i.t., from which direction the station will be tuned in; from low-to-high, or from high-to-low frequency. I followed the convention of tuning in from high-to-low on 7MHz and low-to-high on 14MHz and set the r.i.t. accordingly.

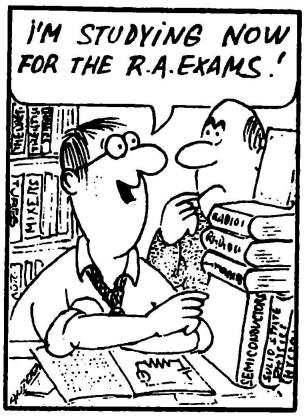
Perhaps the best way to do the setting-up of the r.i.t. is to use the transceiver modules on the test bench feeding into a dummy load of 50 ohms and compare the signals with a little test oscillator and an existing amateur bands receiver. Again, crystals used in the basic form of the transmitter module could be used to provide a setting-up signal in a small test oscillator. Use the station receiver to set the test oscillator and the *PW* "Teme" transmitter output on the same frequency and adjust the modules so that they receive the test oscillator signals at the audio pitch of the filter centre frequency and transmit at the same frequency as the test oscillators. Perhaps a little fiddly but well worth spending some time on getting right as it is counterproductive to go on the air and be calling stations off frequency or have them calling you out of the peak frequency of the audio filter.

Another very simple way to do this adjustment is to have a local friendly amateur conduct a tune-up QSO with you. Get the station to call you and ensure that the receiver is set up so the filter peaks with the RIT control at the centre point. Then call him and adjust the transmit preset until you are on his frequency. This can also be done on the bench with an existing transceiver, which should either be a QRP transceiver or one set for very low r.f. output, and the *PW* "Teme" both running into dummy loads. This time conduct the tune-up QSO across the bench. Remember if the test is done on the air, get your friendly local station to reduce his power to a level that is only ample for the testing procedure and will not annoy other band users.

## Using the Modules

Once the setting-up is completed the *PW* "Teme" can be used in anger on the bands. The most satisfactory way to try out a first QSO is to arrange a sked. Not only does this ensure an instant first QSO but checks out the transceiver in use and allows for any final adjustments that might be required. The transceiver has semi-break-in and pressing the key will energise the transmitter, kill the receiver and bring in the sidetone. Remember to tune in signals from the direction which has been set up for the RIT control. The sophisticated could mark the RIT control so it can be set to tune from either side: very useful for avoiding QRM. Follow the usual QRP operating procedures. Avoid calling CQ, except for occasional "CQ QRP" calls on the QRP channels: 7030kHz and 14060kHz. Instead answer CQ calls or "tail-end" existing QSOs. Remember a QRP signal will probably be some two S-points down on a conventional signal but be bold and a surprising number of QSOs will result.

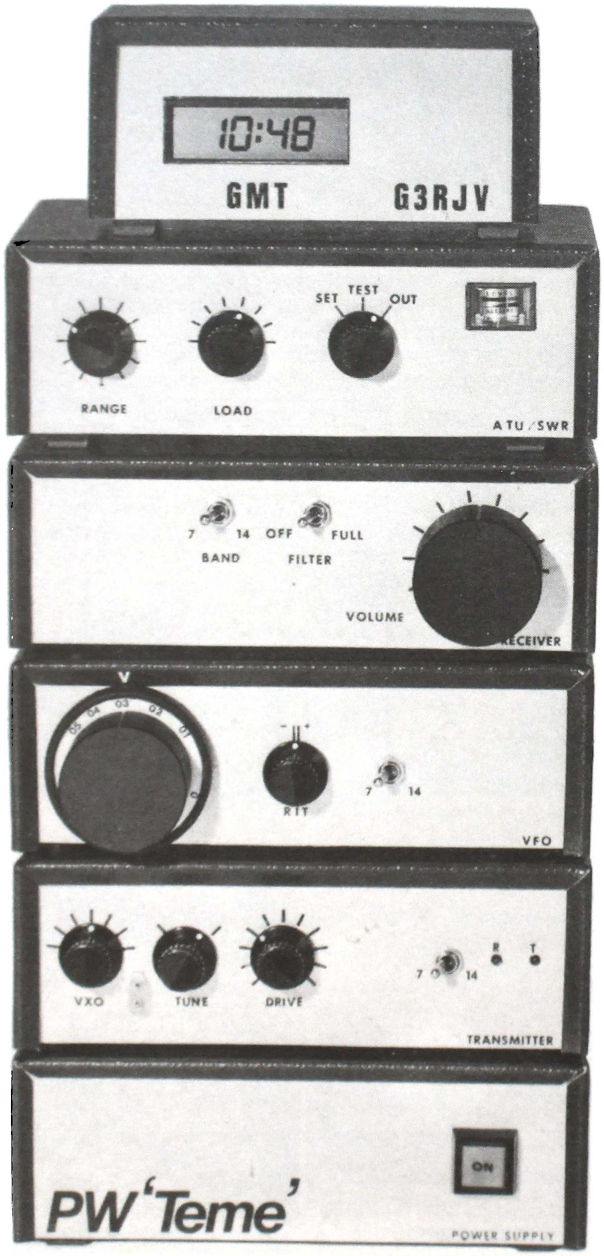
**Benny**



THIS MONTH- ATU/SWR BRIDGE + PSU

# PW 'TEME' Modular QRP Transceiver

Part 4 by Rev. George Dobbs G3RJV




It is standard practice in amateur radio equipment these days to have an r.f. input and output impedance of 50 ohms and the *PW* "Teme" project follows this convention. This is ideal when matching nominal 50 ohm antennas such as dipoles, beams and commercial verticals, but many amateurs use wire antennas which they tune for use on more than one band. This means they require an a.t.u. (antenna tuning unit) to enable the transceiver to "see" 50 ohms. In my view all antennas need an a.t.u. because they are rarely sufficiently broadly tuned to ensure an adequate match across a whole amateur band. Also the a.t.u. aids harmonic suppression and provides a degree of input tuning on receive. This module provides for an a.t.u. and a simple standing wave ratio (s.w.r.) bridge to match the *PW* "Teme" modules to most antennas. For those who do not require the a.t.u. in the line, a switch is provided to allow the s.w.r. bridge to operate alone between the transceiver and the antenna.

## The Circuits

Many are the words but few are the ideas, written about antenna tuning in the amateur radio literature. An a.t.u. is really a device to deceive the transmitter output, by means of combinations of inductance and capacitance, into accepting antennas of various impedance as being 50 ohms terminated. The circuits are legion but they are usually just versions of "L", "T" or Pi ($\pi$) networks or tuned impedance transformers. For general work on more than one band, using "bits of wire" I still favour the first a.t.u. circuit I used 25 years ago: the simple "L" match. It can match a large range of impedances and is very much at home with end-fed lengths of wire tuned against ground or a quarter-wave counterpoise wire.

The "L" match is shown to the right-hand side of Fig. 4.1. The coil, 4L1, is in series with the signal path from transceiver to antenna and the variable capacitor, 4C1, is in parallel with the output to the antenna. Coil 4L1 is tapped giving a choice of inductance values and the tappings are chosen with a 12-way, single-pole, wafer switch, 4S3. Should the constructor be lucky enough to have a roller-coaster coil, one of those splendid continuously-variable inductances of yesteryear, that would be so much better than a switched coil in 4L1. It would not fit into the standard size cases being used in this project but it would ensure a mighty good a.t.u. In this module the a.t.u. section can be switched in or out of the line using a two-pole changeover switch, 4S2. "L" Match a.t.u. circuits are often made to suit a wide range of antenna impedances and the whole h.f. spectrum. In this case, where only the 7 and



*Reprinted from Practical Wireless, February 1985*

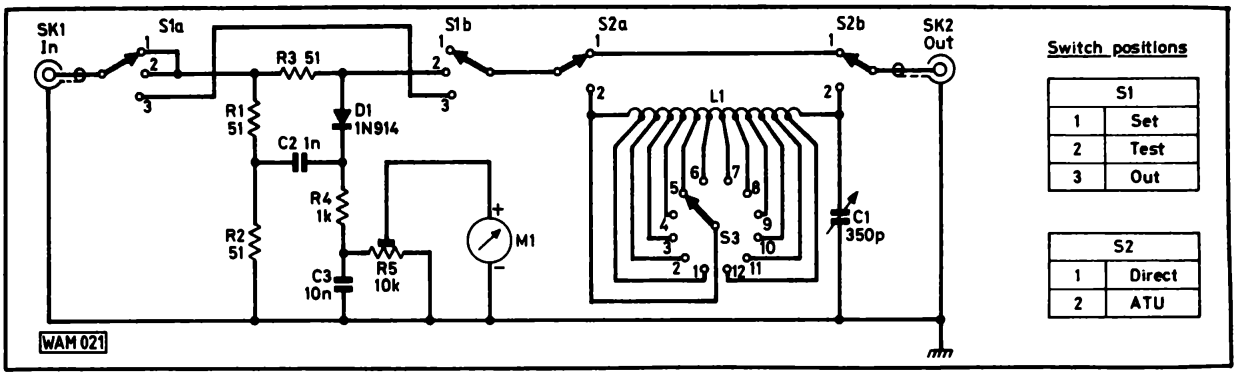



**Fig. 4.1: Circuit diagram of Module 4, the Antenna Tuning Unit/SWR Bridge**

14MHz bands are being used, with most reasonable wire antennas not much inductance will be required, so very few of the switch positions will ever be used.

The standing wave ratio bridge circuit is to the left of 4S2 in Fig. 4.1. I have chosen a resistive bridge as with the *PW* "Severn" (see page 30) to ensure that the transmitter final stage has a reasonable load across its output even during the worst mismatches in the tuning up process. The power amplifier stage in the transmitter of the *PW* "Teme" project is fairly sturdy but many a constructor has suffered from necrophilic transistor p.a. stages. The circuit is just another version of our friend Mr. Wheatstone's Bridge beloved of physics masters in school. Resistors 4R1 and 4R2 form two arms of the bridge, with 4R3 and the antenna load as the other arms. When the bridge is balanced at 50 ohms, an r.f. null will occur between the junction of 4R1/4R2 and the junction of 4R3 and the load. This is rectified by 4D1 into a d.c. voltage (or, rather, a lack of it when the null occurs!) and measured by the meter, 4M1. A variable resistor, 4R5, allows a range of cheap ex-tape recorder meters to be used in the circuit by acting as a meter sensitivity control. One of the disadvantages of this type of bridge is that it must be switched out of the r.f. line once the measurements have been made. This is done with 4S1, a four-pole, three-way, wafer switch. In switch position 1 the r.f. output goes across 4R1 and 4R2, without the antenna in the circuit, to enable the meter to be set to read full scale by using 4R5. Position 2 is the actual operating position for the bridge and in this position the a.t.u. may be adjusted to give a low or null reading on the meter. When this has been attained, positon 3 on the switch cuts out the bridge and gives a direct line between the transmitter output and the a.t.u.

## Construction

The s.w.r. bridge and a.t.u. are built into the Minffordd Engineering type J6 Instrument Case. The a.t.u. section is direct wired between 4S3, 4L1 and 4C1. Coil 4L1 is wound onto a 25mm (1in) outside-diameter former. This can be any low-loss insulation material. A piece of plastics piping or a pill phial would be ideal. The prototype used a Perspex tube which was a 10p coin chute from a scrap fruit machine but more homely tubes may be used and even the diameter is only nominal. The coil is wound with 22 s.w.g. enamelled wire. It has 24 turns with a tapping at every two turns. Wind on the wire tightly and, after each two turns, pull out the wire at right angles to the former, make a small loop (about 6mm) and twist the wire round to form a termination point. It is helpful to stagger these tapping points by slightly offsetting them in twos or threes,

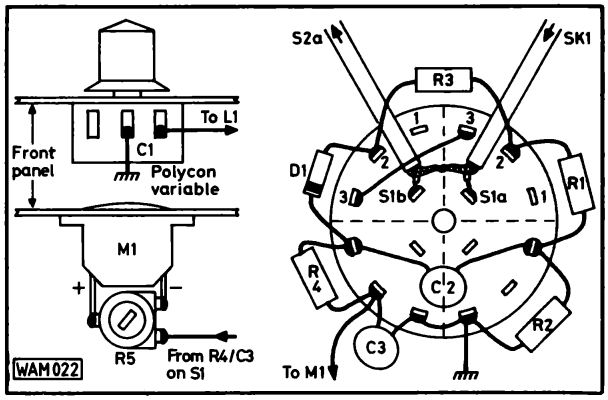
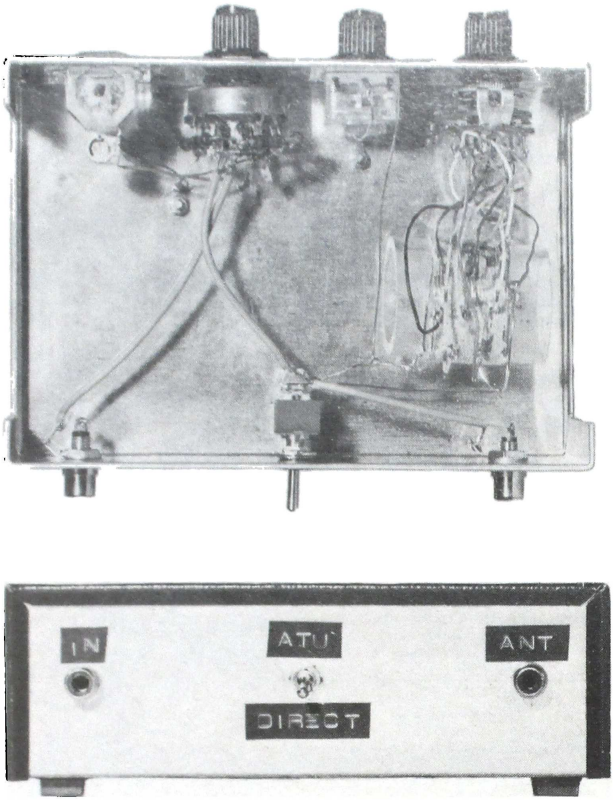



**Fig. 4.2: Wiring details of Module 4**

because if arranged in a straight line the job of soldering the switching wires to them becomes very fiddly. The coil is mounted above the base of the case on standoffs. These should be the correct size to space the coil equally from the top and bottom of the case.

The variable capacitor, 4C1, can be almost any capacitor of suitable physical size with a maximum capacitance in the 200 to 500pF range. The prototype used a Polycon capacitor of the type commonly used as the tuning control in cheap Far Eastern a.m. transistor radios. The transmitter output is such that this type of capacitor will serve quite well in the a.t.u. circuit. This capacitor could be gleaned from a scrap transistor radio but look for a capacitor which has a control shaft long enough to take a tuning knob. If a suitably sized air-spaced capacitor can be found, so much the better. Only one section of the Polycon capacitor is used (there are usually two ganged sections) and it is wired as shown in Fig. 4.2. The termination tags of these capacitors vary from type to type and the constructor may have to inspect the component to choose one section of the capacitor. One tag will be connected to ground via the control shaft. Check which tag is connected to control shaft with an ohmmeter so as not to connect it to 4L1 by mistake and so short out 4C1 to ground.

The s.w.r. bridge is mainly wired around the function switch, 4S1 as shown in Fig. 4.2. The wafer switch may be clearly marked in sections or the constructor may have to identify the various contact tags with an ohmmeter. The main components are mounted onto the back of 4S1 with screened leads taking the signal to and from the switch. The spare sections of the switch are used to provide




**Top and rear-panel views of Module 4, the ATU/SWR Bridge**

## ★ components

**MODULE 4**
**ATU/SWR BRIDGE**

**Resistors**

*½W 5% carbon film*

| | | |
|---|---|---|
| 51Ω | 3 | R1–3 |
| 1kΩ | 1 | R4 |

*Sub-min. horizontal pre-set*

| | | |
|---|---|---|
| 10kΩ | 1 | R5 |

**Capacitors**

*Ceramic*

| | | |
|---|---|---|
| 1nF | 1 | C2 |
| 10nF | 1 | C3 |

*Variable, Polycon*

| | | |
|---|---|---|
| 350pF | 1 | C1 |

**Switches**

| | |
|---|---|
| S1 | 4-p, 3-w wafer |
| S2 | d.p.c.o. min. toggle |
| S3 | 1-p, 12-w wafer |

**Inductors**

L1 24 turns 22 s.w.g. tapped every 2 turns on a 25mm (1in) dia. former

**Miscellaneous**

Meter (see text); Phono sockets (2); Case, Minffordd J6; Feet, knobs (3), etc.

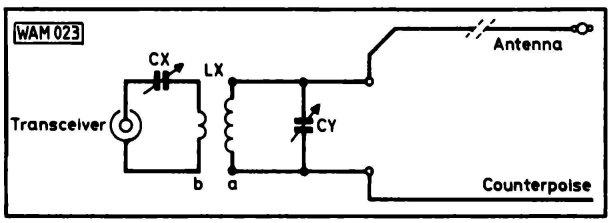
mounting points for the components not directly wired to switch contacts. The wiring for the meter and 4R5 is also shown in Fig. 4.2. The meter is an ex-tape recorder meter bought cheaply at an amateur radio rally. Any moving coil meter with a full scale deflection of 1mA or less is suitable. The meter in the prototype proved to have a full scale deflection of some 200μA but 4R5 will adjust the available meter to suit the bridge. The case layout is shown in the photographs.

## Using the Module

The s.w.r./a.t.u. module requires no external power. It is simply inserted in the antenna line from the main transmit module. The transmitter output goes to the IN socket 4SK1 and the antenna is connected to the OUT socket 4SK2. If an end-fed piece of wire is being used as an antenna, tuned against an earth point, the output socket could be replaced with two terminals for antenna and earth. The module allows for the a.t.u. to be switched out using 4S2 and although the *PW* "Teme" will receive signals with the s.w.r. switch, 4S1, in position 2 or 3 (TEST and OUT), the transmitter should be used with the switch in the third position (OUT).

The setting-up procedure is very straightforward. With the antenna connected and the a.t.u. in the line, the transmitter is keyed with 4S1 in the SET position. This will show if an r.f. signal is being transmitted. In fact this position could be used to adjust the TUNE control in the transmit module for a peak in output. When using the s.w.r. bridge for the first time, 4R5 should be set to allow the meter to read full scale, with 4S1 on the SET position. Once this has been adjusted, that setting should suffice for all future use of the bridge with the transmitter. The switch in now placed in the TEST position. The aim is now to adjust the a.t.u. until the bridge detects a 50 ohm impedance on the antenna output. When this state is achieved, the meter will show a distinct null, indicating nothing, or next to nothing, on the scale. The actual null will be achieved by tuning 4C1 in conjunction with the correct setting of 4S3. Begin by trying to obtain a null with 4C1 and alter the position of 4S3 until a very low reading null point is found. The antenna should now be matched into the transmitter and the s.w.r. bridge can be removed by switching 4S1 to the OUT position. This type of s.w.r. bridge does not give any indication when the transmitter is keyed. Some operators like to see a dancing needle when they key the transmitter and such operators can find an alternative s.w.r. bridge circuit from the *PW* "Severn".

Alternative a.t.u. circuits could be used with the *PW* "Teme". One very suitable arrangement is to use the W3EDP Antenna on both bands. This is a simple antenna that will fit into many domestic situations, does not require an earth and gives a good account of itself with low power. It is shown in Fig. 4.4. The antenna does have a 26 metre




**The W3EDP antenna and its associated a.t.u.**

(85ft) top section but this can be bent around to fit available space. In fact, the antenna seems to work better with a few bends in it to break up the radiation pattern. The two capacitors can be made up from Polycon variables, as with the "L" match capacitor. One section is used for CY but both sections are parallel connected for CX. Again this arrangement was used, for only 7MHz, in the *PW* "Severn" transceiver. The a.t.u. is included again here because it works very well with many antennas which use open-wire feeders. It could match up the *PW* "Teme" to a doublet or, as in my case, it tunes up a G5RV antenna with open feeders. Another possible a.t.u. circuit would be the "T" match circuit usually found in the *ARRL Handbook* as the "Transmatch".

Now that the a.t.u. and s.w.r. bridge are added the project is very nearly complete. All that remains is to add a suitable 12 volt stabilised power supply.

## The Power Supply (Module 5)

The *PW* "Teme" transceiver requires a supply of 12 volts d.c. which should be stabilised and well smoothed. The power requirements of the project are such that a battery supply is quite viable. The prototype has been used with a "Dryfit" sealed lead-acid battery and with a bank of "Cyclon" cells. Either of these render the transceiver portable but for home applications obviously a mains-powered supply is more convenient. Most power supplies capable of giving 12 volts at around 1 amp would be suitable although some of the cheaper power supplies sold for the CB market might not be adequate. The transceiver uses a direct conversion receiver and such receivers are very prone to picking up mains hum from poorly smoothed supplies. This power supply is also built in a matching case which can stack with the other modules in the unit.

## The Circuit

The circuit for the power supply (Module 5) is shown in Fig. 4.4. It contains no surprises, being the standard circuit associated with the three-pin integrated circuit stabiliser. The transformer is a toroidal type; the small physical size of this type of transformer being required to fit the whole supply into the standard J6 type case used throughout this project. The stabiliser i.c. requires some 18 volts to ensure the 12 volt output and the transformer chosen is, in fact, one with two 9 volt output windings which are wired in series to give the required voltage.

The a.c. voltage is rectified using a bridge rectifier capable of handling the voltage with a current rating at least twice the required 1 amp output. There is a whole range of such rectifiers made by various manufacturers. An experienced constructor could use four suitable diodes wired into a bridge circuit for full-wave rectification. The reservoir capacitor 5C1 is a 4700µF electrolytic capacitor rated at 50 volts. This is somewhat more than the theoretically required capacitance but allows for more effective elimination of mains hum. A 1kΩ, 1 watt resistor 5R1 provides a small constant load across the supply which aids stabilisation and also safely discharges 5C1 at switch-off.

Stabilisation is provided by the LM240K-12 integrated circuit, 5IC1. Again other suitable components could be used from the range of 12 volt, 1·5 amp regulator i.c.s. The input and output filter capacitors 5C2 and 5C3 are small tantalum bead types, and are necessary to prevent parasitic oscillation in 5IC1. A switch for the mains supply, a 1 amp fuse and a 12 volt POWER ON bulb complete the circuit. The prototype used a rather smart push-button, on-off mains switch with an integral indicator lamp and lens, but these are expensive. Any mains push or toggle switch with a separate indicator bulb would serve the purpose. The output is taken to a 5-pin DIN Socket, as shown in Fig. 4.4. This matches up with the control line cables used throughout the *PW* "Teme" project.

## Construction

Once again, the power supply module uses the J6 Instrument Case sold by Minffordd Engineering. The layout for the case is shown in the photographs. The LM340K-12 is mounted onto a heatsink on the back of the case. The

## ★ components

**MODULE 5**
**POWER SUPPLY**

**Resistors**
*1 watt 5%*

| | | |
|---|---|---|
| 1kΩ | 1 | R1 |

**Capacitors**
*Electrolytic 50V*

| | | |
|---|---|---|
| 4700µF | 1 | C2 |

*Tantalum Bead 35V*

| | | |
|---|---|---|
| 0·33µF | 1 | C2 |
| 1µF | 1 | C3 |

**Miscellaneous**

Transformer 240V primary, 15VA, 2 x 9V secondaries (ILP Type 02011); Bridge rectifier 50V 2A; Regulator LM340K-12; Fuse, 1A, with holder; Indicator Lamp, 12V 0·1A with holder; Switch s.p.s.t. 240V; Heatsink for TO3 package device (Maplin FL69P or similar); 5-pin DIN socket; Case, Minffordd J6; Mains flex and plug; Feet, etc.

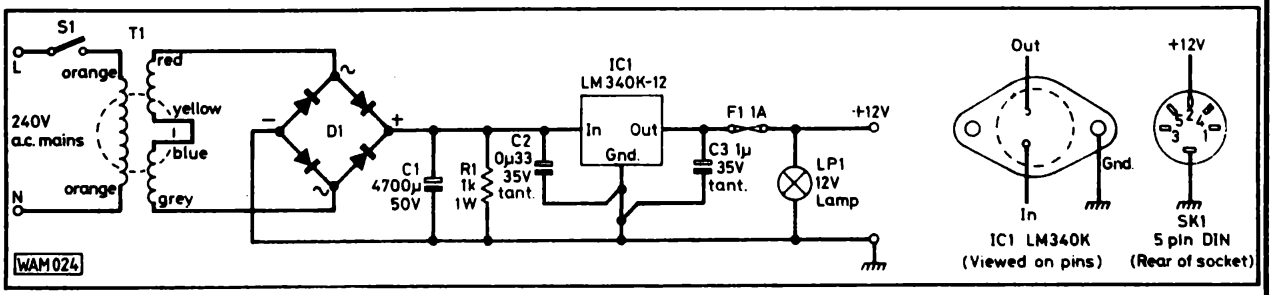
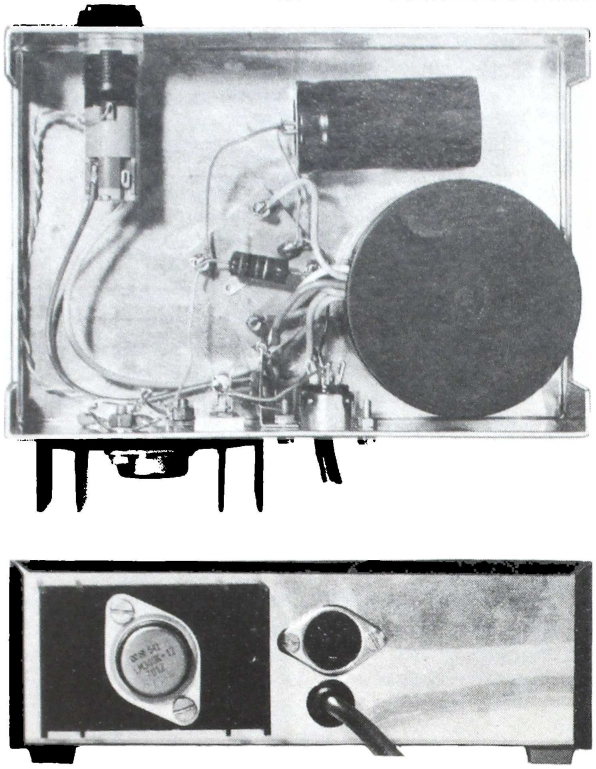



**Fig. 4.4: Circuit diagram of Module 5, the mains-operated power supply**



**Top and rear-panel views of Module 5, the Power Supply**

transformer has a single-hole fixing on the bottom panel and the various small components are directly wired around the fixed items in the case. The filter capacitors, 5C2 and 5C3 should be wired directly onto the pins of 5IC1, as close to the pins as possible and taken to the ground point on the i.c.

The prototype used a fuse inside the case but a panel-mounting fuse might be more convenient. No mains earthing was used on the prototype. Not good safety practice, but when a balanced antenna is being used, as in my case, I do not earth the case of the equipment. **THE RISK IS YOURS.**

## Using the Supply

It is advisable to check the voltage of the supply before it is connected to the transceiver. A 5-pin DIN plug wired into the control voltage lines supplies the transceiver. So, "plumb it in" and use it.

## The Clock

The photographs of the complete *PW* "Teme" system show a digital clock sitting atop the stack of modules. No detailed description of the clock will be given here, as it consists merely of a ready-built liquid crystal display (l.c.d.) module built into a matching case with two momentary-contact push-button switches (for setting the time) and a suitable battery. Modules providing similar facilities are available from suppliers such as Cirkit, or complete clocks at a very reasonable price are offered at car accessory shops.

## Operating a QRP Transceiver

The completed *PW* "Teme" transceiver is a low-powered (QRP) station but is, in spite of the low power levels, capable of successful use on the 7 and 14MHz amateur bands. Remember that the power limitation means that the signal may be some 2 S-points down on a typical signal. As with all low-power operation, skill rather than brute force comes to the fore. Avoid calling "CQ" but instead look for stations making a CQ call and answer them. Another good technique is to "Tailend" an existing QSO. Sort out a required station making a contact, wait until the end of that QSO and quickly call in with a "two by two" (his callsign twice . . . DE . . . your callsign twice). Always remember to wait for that final "73" or "dit-dit" that many stations exchange at the end of a QSO.

Try to avoid letting the other station know too quickly that you are a QRP station. This can be worth 2 or 3 S-points in a report! A lot of useful advice on low-power operating can be found in the QRP section of the RSGB book *Amateur Radio Operating Manual.* Timidity is the enemy of the QRP operator; expect to gain QSOs and they often take place. It is often worth while calling "CQ QRP" on the International QRP Calling Frequencies of 7030kHz and 14 060kHz to enjoy the satisfaction of two-way QRP operating. Satisfaction is what operating a home-built QRP transceiver is all about. Contacts made on a transceiver built by the operator can exceed the satisfaction of those made on the most expensive of commercial stations. The respect that home-built equipment receives on the band can be quite surprising. Revel in the "FB SIGS FOR QRP" and "CONGRATS ON HOMEBREW STATION OM" and enjoy your home-built station. ●

## BUYING GUIDE

**Cases:** The J6 Instrument Case is available from Minffordd Engineering, Sun Street, Ffestiniog, Gwynedd LL41 4NE. (076676) 2572.

The remainder of the components are available from regular *PW* advertisers.

★ ATU/SWR Module £11
★ PSU Module £15

**Approximate Cost** £ ★

**Construction Rating** INTERMEDIATE

**G-QRP Club**

If the idea of QRP operation appeals to you, and you'd like to pursue it further, why not join the G-QRP Club, a specialist group for users and builders of Low Power Equipment. Details from: Fred Garrett G4HOM, 47 Tilshead Close, Druids Heath, Birmingham B14 5LT.

# Practical Wireless

THE RADIO MAGAZINE

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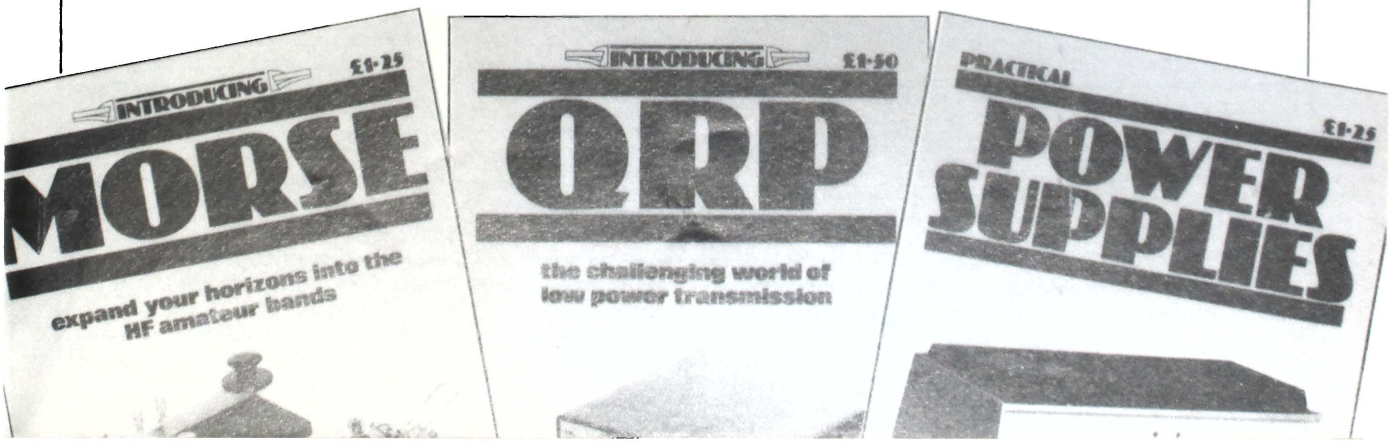
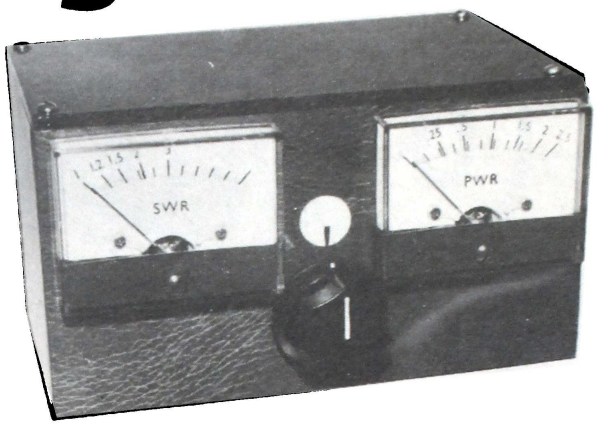


# QRP SWR Bridge

Tony Smith G4FAI




Low power (QRP) operating is becoming increasingly popular nowadays on the amateur bands and offers the advantage that much of the equipment can be home-constructed in simplified form without the need for many of the precautions required when operating at higher power levels.

Opinion on what constitutes low power varies between different countries, and between different operators in those countries, but the G-QRP Club's definition—less than 5 watts input, and the (American) QRP Amateur Radio Club International's maximum of 5 watts output, are the sort of power levels referred to in this article.

Transmitters need to "see" a specified load, usually 50 or 75 ohms, at their output. Whether the antenna in use is already matched to the required impedance, or whether the match is obtained through an antenna tuning unit (a.t.u.), a standing wave ratio (s.w.r.) bridge enables the effect of the load on the transmitter to be monitored and adjusted as required (Fig. 1). Many modern transmitters automatically reduce their output power if a mismatch is presented by the antenna system, and the bridge is then a most useful device to assist in obtaining optimum performance at all times.

When a transmitter transfers power to a feeder line of the correct impedance, and the feeder terminates at an antenna also presenting the correct impedance, all of the power is taken and radiated by the antenna. When the antenna has the wrong impedance, i.e. the feeder is not correctly terminated, a portion of the power is reflected back down the feeder in the form of standing waves. The ratio between the forward power and the reflected power is the standing wave ratio, and the function of an s.w.r. bridge is to indicate that ratio at the point where the bridge is located in the feeder line.

## The Circuit

The design shown in Fig. 2 is a simple unit for QRP operation on all authorised frequencies up to 30MHz, based on a toroidal transformer T1. The secondary winding of T1 samples a small amount of r.f. power (both forward and reflected) which is divided by the bridge circuit and rectified by diodes D1 and D2. Forward and reflected readings are obtained simultaneously on the two meters M1 and M2, and the bridge is matched and balanced at the required load impedance by C1 and C2. Brief details are given in Fig. 5 of an alternative, less expensive, single meter version.

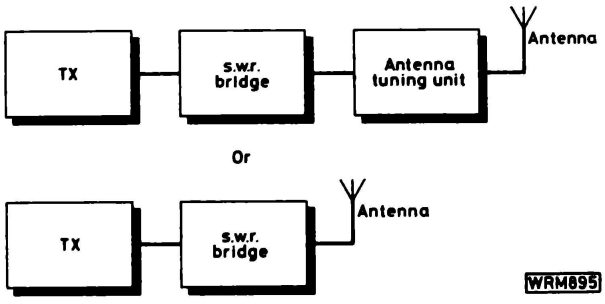



**Fig. 1: Where to place the s.w.r. bridge—the length of feeder between the TX and the bridge should be as short as possible**

The bridge also measures forward power and, although it should not be regarded as a laboratory instrument, its accuracy should be sufficient for all practical purposes.

The project is housed in an easily constructed wood/hardboard case, partly to keep the cost down and partly to enable the constructor to have the satisfaction of creating a completely "home-brewed" unit. A metal case can be used if desired and the feed-through capacitors C4 and C5 would then no longer be required.

## Construction

Details of the case can be seen in the photos. The main assembly is simply held together by nails and glue. Holes for the nails are pre-drilled, slightly undersize, to prevent the wood splitting. The front panel is secured by panel pins and glue and the top and rear panels are secured by woodscrews to facilitate access and setting-up.

In the prototype the nails and panel pins were punched below the surface level of the case and all gaps, holes, and irregularities made good with filler and rubbed down. The case, plus rear panel, was painted inside and out with matt black paint, and the top cover with black gloss. The front and sides were covered with Fablon after the meter holes had been cut out.

The holes for the meters were cut by marking the position of the meters on the front panel and drilling a series of small holes round the inside of the circle. The meter holes were then finished off with a half-round file. Exact details and measurements for meter and potentiometer mounting will depend on the particular meters obtained for the project.

Virtually any meters can be used having a 100μA linear full-scale deflection and these represent the main cost of the project. It is worth getting the best quality possible to ensure a long life in the meter mechanism. Those used in the prototype had a front face size of 60 x 45mm, a panel cut-out of 38mm diameter, and an accuracy of 2·5 per cent.

The components are mounted on Veroboard as shown



*Reprinted from Practical Wireless, October 1983*

in Fig. 3. Matched diodes are required and a simple matching circuit is shown in Fig. 4. The circuit board is fitted on spacers inside a small aluminium box with 15mm woodscrews passing through the board, the spacers, the bottom of the box, and the earthing plate, into the floor of the case.

The input and output sockets are mounted at the rear of the box and holes need to be drilled in the rear panel of the case to allow access to the sockets. Phono sockets were used in the prototype, as these are frequently used for QRP operation, but any type can be fitted to suit the constructor's needs. Care must be taken when fitting the sockets to ensure that they do not prevent the lid fitting properly on the box. Similarly, the box must be fitted in the case leaving room for the lip of the lid between the box and the rear panel.

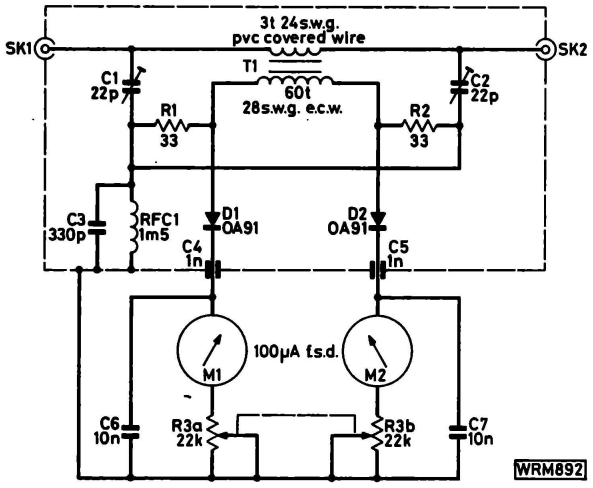



**Fig. 2: The circuit diagram of the QRP s.w.r. bridge**

The connections to the meters are routed via feed-through capacitors, C4 and C5, which are intended to be soldered to chassis. As the box is aluminium this presents some difficulty. In the prototype holes were drilled in the box (making sure the lid was not obstructed) which were marginally smaller than the diameter of the capacitors. The holes were carefully enlarged with the tang of a small file until the capacitors could be secured with a press-tight fit and finally secured with a dab of "super-glue". This arrangement has proved quite satisfactory but purists might prefer to solder the capacitors to a small rectangle of tin plate and bolt the assembly to the side of the aluminium box. The wiring-up of the meters and the dual potentiometer should present no difficulty.

## Setting-up

Once the unit is assembled the bridge needs to be balanced. This is achieved by connecting the TX to one of the rear sockets via a short length of coaxial cable having the same impedance as the TX output. A further length of the same cable connected to the other socket should be terminated by a non-inductive dummy load of the same impedance. This can be made up from one or more carbon resistors to obtain the resistance and wattage required.

If a radio-frequency (r.f.) carrier, at the highest frequency to be used, is now applied through the unit one meter should indicate a high, and the other a low, reading.

## BUYING GUIDE

The components used for this project can be obtained from many of the advertisers in *PW*.

**Approximate Cost** £15

**Construction Rating** BEGINNER

The trimmer capacitor on the side of the bridge showing a low reading (reflected power) should be adjusted to obtain the lowest possible reading. The connections to the sockets should then be reversed and the same adjustment made with the trimmer for the second meter. This procedure may have to be repeated once or twice until finally both meters, when indicating reflected power, read zero, and the bridge is then balanced. During this process the potentiometer should be adjusted so that whichever meter is indicating forward power is set at full-scale deflection.

## Calibration—SWR

Either meter can be used for forward or reflected power indication, depending on which socket is used for input or output. For s.w.r. readings both meters are used and that showing forward power needs only to indicate f.s.d. For reflected power opinions differ on the need for detailed calibration. The most important marking is at a point exactly halfway across the scale which represents an s.w.r. of 3:1. Any s.w.r. in excess of that is undesirable, and in some cases may be detrimental to the TX in use. An s.w.r. of 2:1 is more acceptable, especially with low power, but overall with QRP working the aim should be to achieve a ratio of 1:1 which is a meter reading of zero.

In one sense, therefore, there is only a need for a centre marking to indicate maximum permissible s.w.r. whilst the aim is simply to get a minimum reading as near to zero as possible. More detailed calibrations are shown on the front cover providing an indication of intermediate ratios.

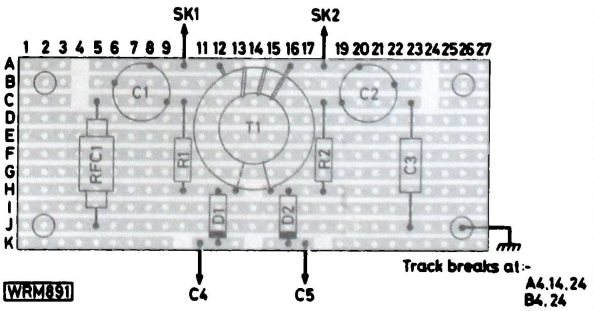



**Fig. 3: The component locations on the Veroboard; the mounting holes should be drilled very carefully to avoid damaging the board**

## Calibration—Power

Forward power readings can also be obtained since the circuit provides a reasonably uniform indication of r.f. power, irrespective of frequency, over its range of operation.

Calibration does, unfortunately, require an external means of measuring r.f. power for comparison purposes, and the article on page 61 describes a simple wattmeter which will fulfil this function. Basically, for those already having access to r.f. measurement, the forward meter is set to f.s.d. when the desired maximum r.f. power passes through it into a dummy load. The setting of the pointer on the control knob is then noted, i.e., a mark is made on the front panel so that the setting can be returned to whenever power readings are required. With the control at this setting further, lower, r.f. powers are fed through the unit and the meter scale marked accordingly.

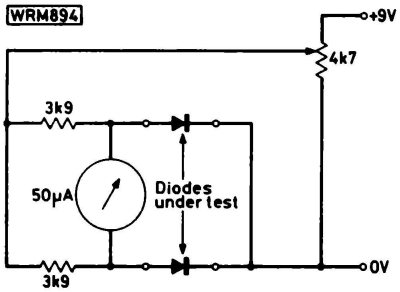



**Fig. 4: A simple diode matching circuit. The two resistors should be matched with an ohmmeter. As the voltage is increased by rotating the potentiometer the meter should not deflect more than 1μA from its no-current setting. It may be necessary to test several diodes before a matched pair is obtained**

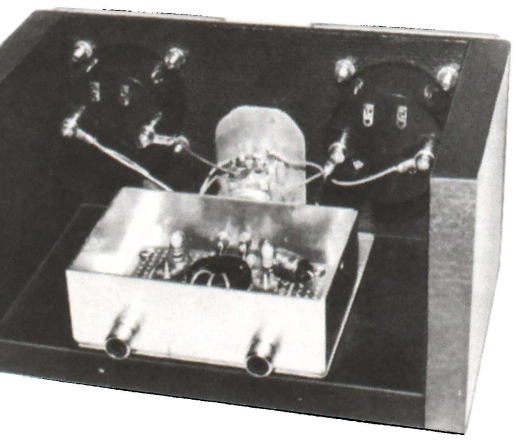
## Operation

The bridge should be connected to the TX as already described. The output can either be connected to an antenna via an a.t.u. or directly to a coaxially fed antenna.

Power is applied from the TX and the meters observed. An a.t.u., if used, should be adjusted to obtain minimum s.w.r., which in most cases should be 1:1. Care should be taken to ensure that the forward meter reads f.s.d. but the pointer should not be allowed to go further so that it is against the end-stop as this may damage the meter.

If the bridge is connected directly to an antenna feed line it will show the s.w.r. presented by the antenna system to the bridge without any immediate adjustment being possible. By checking the s.w.r. at different frequencies across a band it will, however, show the effective bandwidth of the system and indicate whether alterations to the dimensions of the antenna are necessary to bring it to resonance at a higher or lower frequency.

By leaving the bridge permanently in circuit the effect of the antenna system on the TX output can be constantly monitored and frequency changes effected quickly, es-



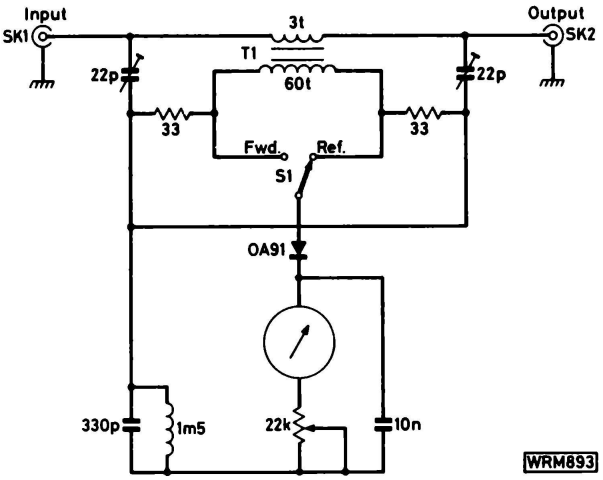



**Fig. 5: A single meter version of the s.w.r. bridge**

## ★ components

**Resistors**

*Carbon film ¼W 5%*

| | | |
|---|---|---|
| 33Ω | 2 | R1,2 (Matched, see text) |

**Potentiometers**

*Dual-ganged*

| | | |
|---|---|---|
| 22kΩ (Lin) | 1 | R3 |

**Capacitors**

*Ceramic*

| | | |
|---|---|---|
| 10nF | 2 | C6,7 |

*Feed-through*

| | | |
|---|---|---|
| 1nF | 2 | C4,5 |

*Polystyrene*

| | | |
|---|---|---|
| 330pF | 1 | C3 |

*Miniature trimmer*

| | | |
|---|---|---|
| 2–22pF | 2 | C1,2 |

**Semiconductors**

*Diode*

| | | |
|---|---|---|
| OA91 | 2 | D1,2 (Matched, see text) |

**Miscellaneous**

Meter 100μA f.s.d. (2); RF Choke 1.5mH (1); Toroidal core T68-2 (1); Veroboard 0.1 inch matrix 24 holes x 10 tracks; Metal box 73 x 51 x 25mm; Phono sockets (2); Pointer knob; Enamelled copper wire 28 s.w.g. (1.3m); Insulated wire 24 s.w.g. (100mm).

pecially when an a.t.u. or alternative antennas are in use. It should be borne in mind, however, that a satisfactory s.w.r. indication on the meter does not necessarily mean that an antenna is performing well. The s.w.r. is measured only at the point in the feed line where the bridge is located and not (usually) at the antenna itself. A dummy load illustrates this point. It can present an s.w.r. of 1:1 through a matching feeder and yet be virtually non-radiating.

With an effective antenna the bridge is invaluable, but its only constant function is to give warning if too high an s.w.r. is presented to the TX output terminals.

An s.w.r. bridge is a valuable part of every radio operator's station. It is a useful tool when constructing antennas and exercises an essential control function when they are in use. Because of its simplicity it is an ideal project for home construction, especially for beginners, and with good quality components it will last for years. QRP operation itself offers enormous scope for home construction and experimentation and a unit such as this should be an integral part of every QRP station.

## Warning

The unit as described is suitable only for low power operation. The circuit is capable of operation up to about 100 watts but different components, and a different form of construction, would be required to take account of the higher power requirements. ●

# QRP RF Wattmeter

Tony Smith G4FAI

Measurement of r.f. power is often thought to be difficult or expensive. This is a simple project which contradicts both assumptions, provided meters or multimeters and a d.c. power supply are readily available, as is quite likely in the average radio amateur's shack. It is described in its basic form and also in a slightly more exotic version having variable instead of fixed components to permit experimentation and greater flexibility in use.

As described it is intended for QRP (low power) measurement but higher powers can be measured by using more substantial components and a higher voltage source.

## Basic Circuit

When r.f. is applied across R1 (Fig. 1) the a.c. peak voltage developed is rectified by diode D1 and this charges capacitor C1 to the same peak voltage.

The voltage activates meter M1 which has previously been calibrated in watts by the application of volts d.c. via S1 as explained later. R1 is, in effect, a dummy load of 50 ohms capable of dissipating the power to be measured. As an example, 3 x 150 ohms 1 watt non-inductive resistors in parallel would provide a 50 ohm, 3 watt, load.

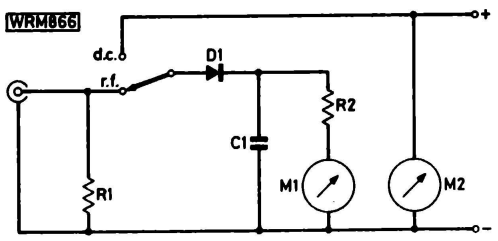
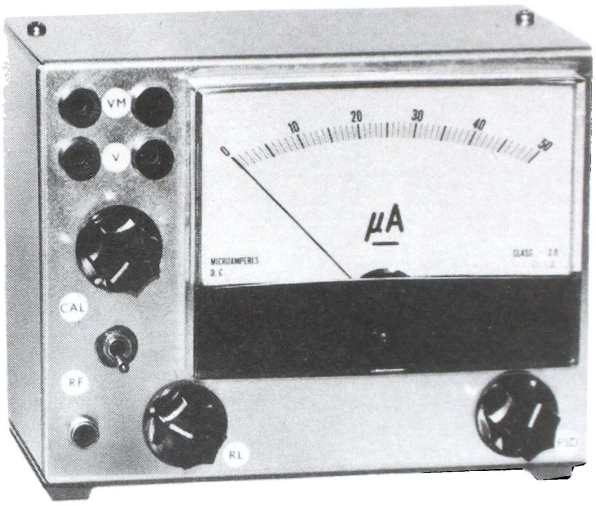



**Fig. 1: The basic circuit**

Meter M1 can be external to, or built into, the unit. A 50–100μA meter is required, or a multimeter set to the appropriate range. R2 is a series resistor, the value of which is calculated to permit full scale deflection (f.s.d.) of the meter at the maximum voltage to be used for calibration.




Meter M2 is an external voltmeter or multimeter for measuring the applied voltages used in the calibration calculations. The voltage supply must be variable in order to calibrate different power levels. If only a fixed voltage supply is available the circuit can be adapted to provide a variable supply.

## Calibration

Resistor R2 is required to set the meter (M1) at f.s.d. for the maximum power to be measured. The calibrating voltage E for this power can be obtained from:

$$E = \sqrt{2RW}$$

where W is the power to be equated to volts and R the value of R1. If, for example, W = 2·5 watts and R = 50 ohms then

$$E = \sqrt{2{\cdot}5 \times 100} = 15{\cdot}81 \text{ volts}$$

The series resistance R2 can now be calculated using Ohm's Law:

$$R = E/I$$

where E is the voltage required to give f.s.d. and I is the sensitivity of the meter, say 50μA.

$$R = \frac{15{\cdot}81}{5 \times 10^{-6}} = 316\,200 \text{ ohms}$$

A series resistor of this value will, therefore, result in f.s.d. on the meter when 15·81 volts d.c. is applied via S1. If S1 is switched to r.f. an applied r.f. power of 2·5 watts will also result in f.s.d.

Calibration for lower powers can be made by use of the same formula, $E = \sqrt{2RW}$, and this is all that is necessary if the wattmeter is to be used for one power range only, e.g., 0–2·5 watts.

Alternatively using $W = E^2/2R$ enables any given calibration voltage to be equated to r.f. power.

## Variations

If R1 could be made adjustable this would enable an exact resistance value to be selected for the load. It would also permit the output impedance of a transmitter to be checked by adjusting the load, and subsequently measuring its value, to obtain minimum indication on an s.w.r. bridge.

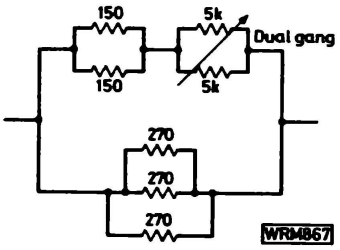



**Fig. 2: A variable QRP load**

A method of obtaining a variable QRP load is shown in Fig. 2. The limiting factor is the power rating of the potentiometer used with the fixed resistors. Standard potentiometers are usually rated about 0·5–1 watt with linear progression but only half that if logarithmic. A constructor intending to try this arrangement should check the power rating of the component to be used with the supplier. In the example shown a 1 watt dual potentiometer is used with the gangs in parallel to give a rating of 2 watts which, in the circuit given, will provide a variable load from approximately 40 to 85 ohms with a conservative dissipation of 3 watts.

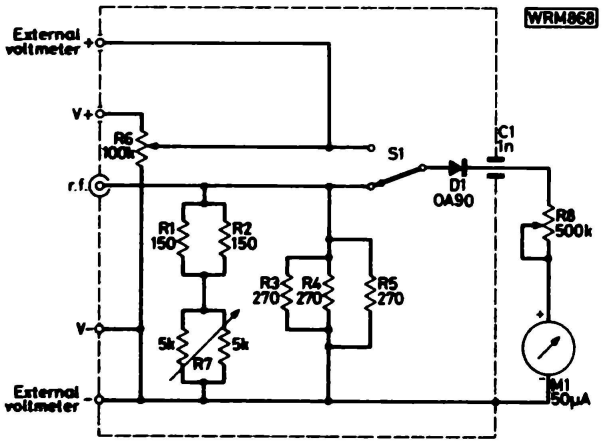



**Fig. 3: The circuit diagram of the prototype. Note that C1 is now a feed-through capacitor providing r.f. isolation for M1 as an additional function**

Another useful variation is to make R2 adjustable. This enables instant achievement of meter f.s.d. if different power ranges are to be used, simply by substituting a 500kΩ linear potentiometer for R2.

If a variable power supply is not available a fixed supply can be used across a 100kΩ linear potentiometer with the slider providing the variable voltage required, and also the point where the voltage can be measured.

A prototype was made up incorporating the variations discussed and the circuit is shown in Fig. 3.

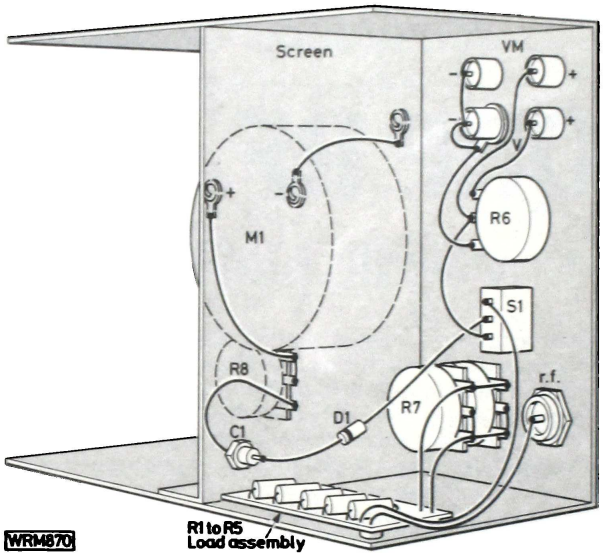



**Fig. 4: A cutaway internal view of the prototype. Note the voltage input earthing tag is taken from the phono socket and carefully enlarged to fit the thread of the wander plug socket. The feed-through capacitor is soldered to a washer or piece of tinplate which is then bolted to the dividing screen**

## Construction

The unit is housed in a standard aluminium box. Layout of the prototype is given in Fig. 4. An extra large faced meter was used in order to obtain a clearly numbered and divided scale. No attempt was made to calibrate the meter

## BUYING GUIDE

Pot R7 is available from Crescent Radio, 21 Green Lanes, Palmers Green, London N13 4TT. Tel: 01-888 3206

**Approximate Cost** £7·50

**Construction Rating** BEGINNER

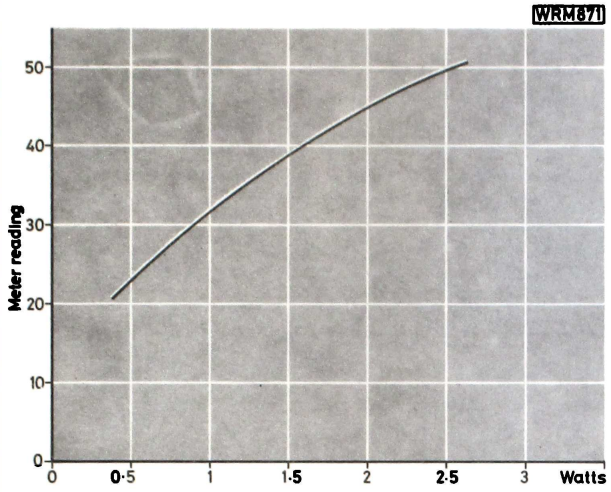



**Fig. 5**

since it was decided to make up tables and graphs for various power ranges to be read off from the existing 0–50 scale (Fig. 5). Three pairs of connecting leads were made up—for the calibrating power supply; the external voltmeter; and for measuring the load resistance via the r.f. input socket. The final terminations of these leads depend on the meters and power supply to be used.

As described there is a certain amount of simple metal work required, holes to be drilled, a slight cutting away of part of the case to clear the components mounted at the front, and a dividing plate fitted internally to provide r.f. isolation between the meter and the load. A larger case, or smaller meter, would simplify this process. The fixed resistance dummy load assembly is shown in Fig. 6; it should be mounted at the bottom of the case via two spacers as shown in Fig. 4.

## Calibration Procedure

1) Decide on the range required.
2) Calculate the calibration voltage for maximum and intermediate power as described in the section on Calibration. Note the powers and corresponding voltages on the chart—see Fig. 5 for an example.
3) Turn CAL and FSD controls fully anti-clockwise.
4) Switch to CAL and connect the power supply and external voltmeter (M2) via the appropriate sockets.
5) Advance CAL control until M2 indicates the desired maximum voltage.
6) Adjust the FSD control for full scale deflection on M1.
7) Note the meter (M1) reading and the chart against the voltage.
8) Reduce the CAL control to the next lowest voltage and note the scale reading as before.
9) Continue with consecutively lower powers.
10) Draw the graph using the data obtained.
11) Switch to RF. Connect the unit to the transmitter. Use the meter indication and graph to read off the power in watts.
12) If graphs are prepared for other ranges, repeat processes 3) to 6) before using the unit for any particular range.

| W | 2·5 | 2 | 1·5 | 1 | 0·5 |
|---|---|---|---|---|---|
| E | 15·81 | 14·14 | 12·25 | 10·00 | 7·07 |
| Meter Reading | 50 | 45 | 39 | 32·5 | 23 |

**Example: 0·5—2·5W range into 50Ω load using formula $E = \sqrt{2RW}$**

## ★ components

**Resistors**
*Carbon 1W*

| | | |
|---|---|---|
| 150Ω | 2 | R1,2 |
| 270Ω | 3 | R3,4,5 |

**Potentiometers**
*Dual-ganged*

| | | |
|---|---|---|
| 5kΩ + 5kΩ (lin) | 1 | R7 |

*Single*

| | | |
|---|---|---|
| 100kΩ (lin) | 1 | R6 |
| 500kΩ (lin) | 1 | R8 |

**Capacitors**
*Feed-through*

| | | |
|---|---|---|
| 1nF | 1 | C1 |

**Semiconductors**
*Diodes*

| | | |
|---|---|---|
| OA90 | 1 | D1 |

**Miscellaneous**
Meter 50μA f.s.d.; Socket (see text); Wander plugs and sockets red (2), black (2); Miniature toggle switch s.p.d.t.; Case 152 x 114 x 76mm Maplin AB31; Veroboard 0.1inch matrix 24 holes x 10 tracks; Spacers 6BA x 6.5mm (2); Nuts, washers and screws 6BA x 12mm (5); Solder tag 6BA (1), Aluminium sheet 130 x 90mm.

The most obvious use of the unit is to measure the output power of a QRP transmitter into a given load. The load is usually the stated output impedance of the transmitter, but equally it could be the known impedance of a particular antenna. One fascinating application is to use the wattmeter to set the transmitter output to, say, 100mW and see how far it is possible to work with that level of power.

The unit can be used to calibrate the forward power of an s.w.r. bridge of the type described elsewhere in this issue. When varying levels of r.f. power are applied through the bridge to the wattmeter the readings from the latter can be noted and used to calibrate the scale of the bridge using the needle of the s.w.r. meter as a marker. To obtain reasonable accuracy the bridge should be balanced against the same load impedance as the wattmeter before calibration.

If an a.t.u. is used with the transmitter, comparisons can be made between power delivered direct to the wattmeter and via the a.t.u. This may reveal power losses through the a.t.u. which can be minimised by experimenting with other a.t.u. settings.

In construction or adjustment work the meter can be used to compare output power with d.c. input to the out-

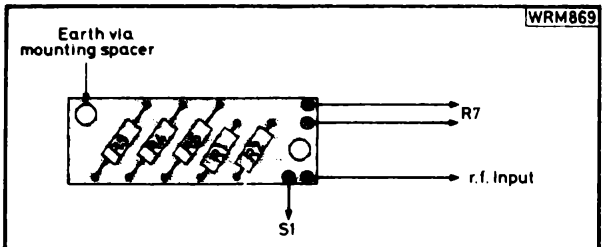



**Fig. 6: The fixed resistance dummy load assembly**

put stage. With QRP working the efficiency of this stage can make the difference between success and failure, and the wattmeter is an invaluable tool for assessing this efficiency.

Mention has already been made of a method of checking the output impedance of a transmitter and no doubt the keen experimenter will find other useful and interesting applications for the unit.

This is an interesting project which can be made in a number of ways enabling the constructor to meet his own particular requirements. It is possible to obtain ±5 per cent accuracy if the components and values used in the formula are measured accurately. The meters should have a sensitivity of at least 20k ohms/volt and the better they are the more accurate will be the power indication. ●

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